Investigation of factors relating to the insect infestation of chocolate-based consumables.

by

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B.Sc. (Hons.)

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the requirements for the degree of
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Dedication

I dedicate this thesis to my two sons, Zachary Sebastian and Ethan Jack, both born during this study and, themselves, a most enlightening undertaking.

Declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution and that, to the best of my knowledge and belief, contains no material previously published or written by another person, except when due reference is made in the text of the thesis.

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March 1996

Authority of Access

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Terence Graham Bowditch

Publications

From research undertaken in this study, the following paper has been published:

Bowditch T. G., Madden J. L. and Brassington B. F. (1994) Field evaluation of a cylinder trap design for monitoring *Ephestia cautella*. In *Proc. 6th Int. Work. Conf. Stored-Prod. Prot.* (Edited by Highley E., Wright E. J., Banks H. J. and Champ B. R.), pp. 1233-1234. Canberra, Australia, 1994.

A copy of this paper can be found at the rear of this thesis.

From other studies undertaken in this research program, which are described in Chapter 4 of this thesis, the following paper has also been accepted for publication:

Bowditch T. G. and Madden J. L. (in press) Spatial and temporal distribution of *Ephestia cautella* (Walker) (Lepidoptera: Pyralidae) in a confectionery factory: causal factors and managment implications. *J. stored Prod. Res.*

Abstract

The aim of this study was to examine the factors relating to insect infestation of produce manufactured at the Cadbury Schweppes' Tasmanian confectionery plant, in order to determine means by which the incidence of product infestation could be minimized. Analysis of the company's infestation-related consumer complaint databases revealed that: assortments (boxed-chocolates) were most likely to be infested; the geographic distribution of complaints was temperature-dependent; 'old' stock and/or produce manufactured during spring was most likely to be infested; infested goods were more likely to be purchased from smaller retail outlets and; the costs associated with infestation were substantial.

Phycitine moths were almost exclusively responsible for infestation, and it was estimated that most cases of infestation occurred post-packaging, most likely while stock was in the hands of independent wholesalers and retailers. A small proportion of infestation probably originated at the Hobart plant, caused by a resident population of the almond moth, *Ephestia cautella* (Walker). This population was traditionally suppressed by the blanket application of synergised pyrethrins throughout the factory, although, an extensive pheromone trapping program indicated that the spraying of pyrethrins affected neither the distribution of *E. cautella*, nor the capture rate, and the distribution of *E. cautella* within the factory was primary dependent upon hygiene conditions. A single room within the factory was identified as the primary source of migratory *E. cautella*, and a control strategy, based on the mass trapping technique, successfully reduced *E. cautella* numbers in this room to negligible levels. The influence of trap design on *E. cautella* catch was also evaluated.

Aspects of phycitine ecology with regard to the post-packaging infestation of produce were examined, and it was found that both adult and juvenile phycitines responded positively to odours escaping from chocolate boxes. The integrity of packaging significantly influenced the likelihood, and extent, of infestation, while the polyvinyl chloride film used to overwrap assortment boxes was found to be readily penetrated by several stored-product insect species. An alternative polypropylene film offered significantly improved insect barrier properties.

A number of measures aimed at minimizing both pre- and post- packaging infestation were recommended. At the factory, it was recommended that an insect pest control strategy relying on advanced insect detection methods and improved sanitary procedures, supported by an appropriate management structure, be adopted in preference to the current chemical-based strategy. With regard to post-packaging infestation, it was recommended that wholesalers and retailers be educated about the dangers that stored-product insects pose to goods, and methods through which insect apparency can be minimized. It was also recommended that the utility of packaging materials and/or technologies that completely retained odours and provide superior insect barrier qualities be investigated. Also, that quality control procedures be implemented to monitor the integrity of product packaging.

Acknowledgements

I would like to thank my supervisor at the Department of Agricultural Science, University of Tasmania, Australia, Dr John Madden for giving me the opportunity to undertake this research project, and for much knowledgable input into the research. I would also like to thank the department's 'Mr Fix-it', Mr Bill Petersen for invaluable technical assistance.

I would like to thank my co-supervisor at Cadbury Schweppes' Claremont factory in Tasmania, Australia, Mr Bryan Brassington for allowing me access to all information, personnel and company facilities I required. I would also like to thank Bryan for sparing much of his valuable time to pass on to me some of his vast knowledge of the confectionery industry.

Without the cooperation and assistance of many other personnel at the factory, this research project would have been impossible to undertake. I would like to thank the manager of the Quality Assurance department, Mr John Aston for his interest and encouragement during the course of this project which was much appreciated. I would also like to thank Mr Peter Ralph and Ms Ruby Hodgetts who helped me procure many of the materials and much of the information vital for my research. I would also like to thank Peter and Ruby, and the other members of the Quality Control department, Mr Allan Pryer, Mr Bob Appleby, Mr George D'louhy and Mr Krys Rudzki, for creating a relaxed and enjoyable atmosphere in which to work. I thank Mrs Star King for undertaking on my behalf a mind-numbing package integrity survey, and Mr Jeff Hey for providing me with materials and information necessary to undertake vital packaging experiments. I also thank Mr Richard Berry for providing much useful information concerning the conditions stock is subjected to once it leaves the factory and general sales information (and a constant stream of particularly poor jokes).

I would particularly like to thank the factory's Pest Control Officer, Mr Peter Newell. While others in his position might have viewed my presence at the factory with a degree of mistrust, Peter was never anything other than completely open and honest, which I believe is of credit to his character. Without Peter's willing assistance and cooperation in imparting his extensive knowledge about the insect pest situation at the factory, this research program would not have proceeded anywhere near as efficiently as it did.

I thank Dr Noel Davies of the Central Science Laboratory, University of Tasmania, for undertaking headspace analyses on my behalf, and Mr Michael J. MacQuillan, from Dunlace International, Sydney, Australia, for supplying six black stripe moth traps (AgriSense, UK) for trapping studies.

I am indebted to my love and soul-mate Ms Trudi Wharton for looking after me and keeping me relatively sane during the last five years, and mothering our gorgeous sons Zachary Sebastian and Ethan Jack. I am also indebted to my parents David and Jan Bowditch for providing me with a happy and stable upbringing, and my sister Anita Knapp. I also wish to thank Trudi's mother, Joy, for being an excellent mother-in-law to me, and an excellent grandmother to the boys.

Finally, I would like to thank our Hobart support crew, Dr's Ann Kitchener and Martin Steinbauer, Kristin Groom, Graham Osler and Jane Giblin, and our interstate cronies David and Andrea Hardcastle.

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CHAPTER 1

General introduction, research objectives and literature review

1.1 GENERAL AIM, COLLABORATIVE PARTNERS AND FUNDING

The aim of this study was to investigate the factors influencing insect infestation of chocolate-based consumables manufactured at Cadbury Schweppes' Tasmanian plant. A key requirement of the research was that it remain relevant to, and advance the field of, stored product entomology. The study was a collaborative project between the Department of Agricultural Science at the University of Tasmania, Australia, and Cadbury Schweppes Pty. Ltd., and was funded primarily by an Australian Postgraduate Research Award (Industry) scholarship with financial and 'in kind' contributions from Cadbury Schweppes Pty. Ltd.

1.2 DESCRIPTION OF THE CONFECTIONERY FACTORY AND PRODUCT RANGE

The factory (Fig. 1) is located in Claremont (147° 15′S, 42° 48′E), a suburb of Hobart, the capital city of Australia's most southern state, Tasmania (Fig. 2). Claremont was originally chosen as the site for a confectionery factory because of the cool, temperate Tasmanian climate and the year-round abundance of high quality dairy pasture. The Claremont factory became operational in 1928 and has since become an integral part of Hobart's economic and social fabric, employing many local workers, sponsoring local events, and becoming a major attraction of the tourist industry.

The factory manufactures a wide variety of chocolate-based confectionery and food products for both the domestic and export markets. Products are broadly classified into 7 categories or 'product groups': (1) 'moulded' block products (Fig. 3a), which make up the bulk of production ; (2) 'assortments', which are boxed chocolate varieties (Fig. 3b); (3) 'bars', which are a range of chocolate bars (Fig. 3c); (4) 'children's' products, which comprise novelty items aimed at children (Fig. 3d); (5) 'food' products consisting primarily of powdered cocoa, powdered drinking chocolate and cooking chocolate (Fig. 3e); (6) 'pic'n'mix' products which are bulk lots of individual confectionery items (Fig. 3f) and ; (7) 'self' products which comprise small, peppermint cream units sold individually at retail outlets (Fig. 3g). A

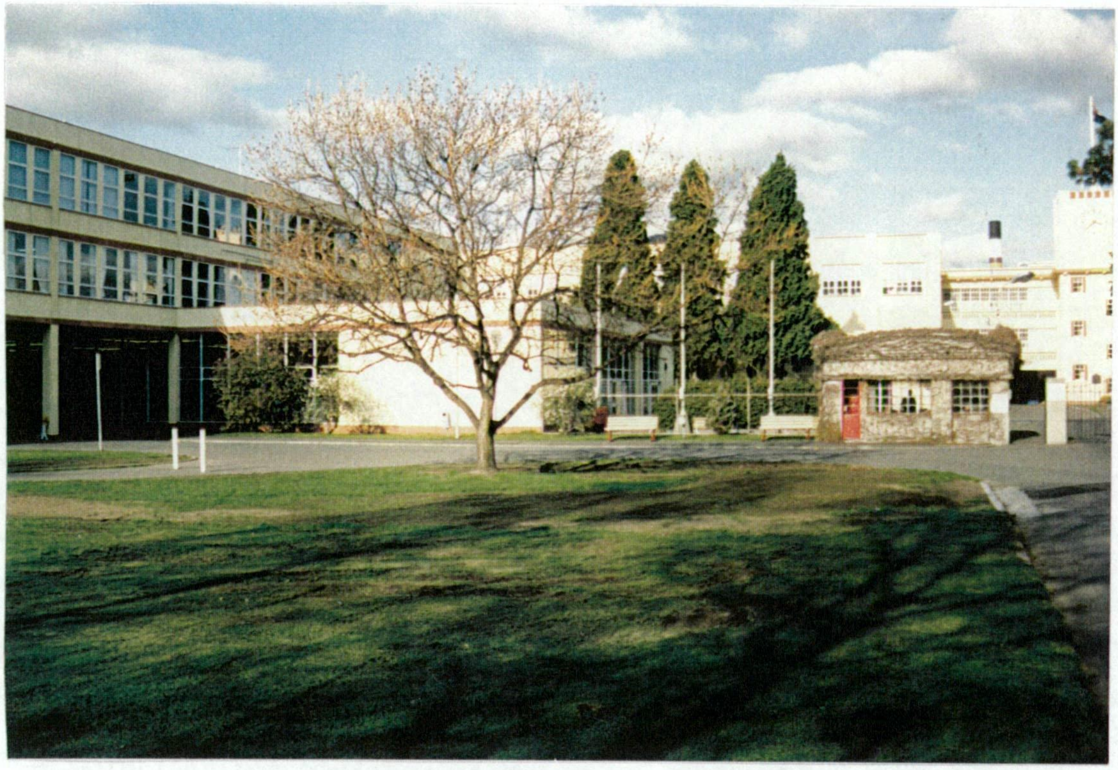


Fig. 1. Cadbury Schweppes confectionery factory located in Hobart, Tasmania.

Fig. 2. The states and territories of Australia. ACT - Australian Capital Territory, NSW - New South Wales, NT - Northern Territory, QLD - Queensland, SA - South Australia, TAS - Tasmania, VIC - Victoria, WA - Western Australia.

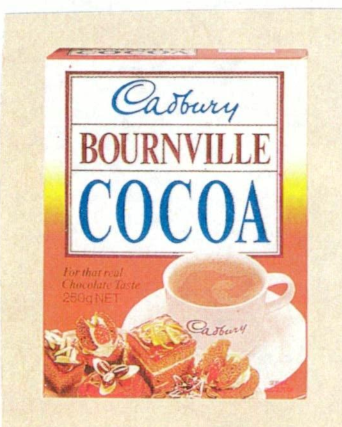
(a)

(b)

(c)

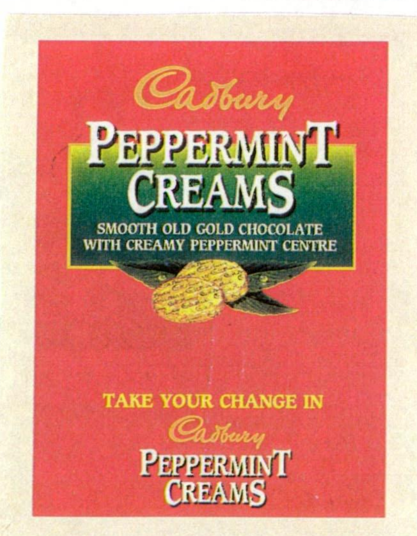
Fig. 3. Examples of products that comprise each of the product groups manufactured at the Claremont plant: (a) Moulded; (b) Assortments; (c) Bars.

(d)



(e)

(f)



(g)

Fig. 3. Examples of products that comprise each of the product groups manufactured at the Claremont plant: (d) Children's; (e) Food; (f) Pic'n'mix; (g) Self.

comprehensive list of the individual product types that comprise each product group can be found in Appendix I. In total, almost 30,000 tonnes of produce is manufactured annually, much of which is sold domestically from almost 14,500 retail outlets throughout Australia.

1.3 THE CONSEQUENCES OF INSECT INFESTATION

Insect pests can cause extreme damage to many of the products manufactured at the Claremont plant (Fig. 4) by both devouring goods and defiling them with webbing, frass, exuviae, and whole or fragmented carcasses. Consumers purchasing such items will obviously be dissatisfied with the product's quality, and this can have serious consequences for the manufacturer (Fig. 5). Investigation and/or legal proceedings by local or overseas health authorities over insect contamination has obvious adverse ramifications for any food manufacturer, but particularly for one such as Cadbury Schweppes which is attempting to enter new export markets.

The results of a consumer quality survey conducted by Sensory Market Analysis and Research Technology (SMART) in 1992 put into perspective how consumer dissatisfaction with quality faults can rapidly affect company profitability and image. The survey showed that, upon purchasing a product containing foreign matter (e.g. sticks or hair), three quarters of consumers would either stop buying that product or switch to another brand, and only 7% of consumers would continue to buy the product. Further, the survey found that, the vast majority of consumers (84%) would complain to their friends, so the product may rapidly gain a name for poor quality in the wider community. Almost all consumers (94%) would feel annoyed with the company, 83% would take the product back to the place of purchase, and two thirds of consumers would either write or phone a complaint to the company. While the survey found that a foreign matter (eg. sticks or hair) quality fault produced the strongest negative reaction by consumers, a product infested by insects may evoke an even stronger reaction due to the more offensive nature of the fault. Therefore, the infestation of chocolate-based consumables not only has the potential to rapidly affect Cadbury Schweppes' profitability, but also to damage the company's reputation as a manufacturer of high quality foodstuffs.

Fig. 4. Insect damage to produce manufactured at the Claremont plant. Top - 'Nut caramel' assortment unit; Bottom - 'Hazelnut whirl' assortment unit.

Fig. 4. Insect damage to produce manufactured at the Claremont plant. Top and bottom - 'Hazelnut milk' moulded block.

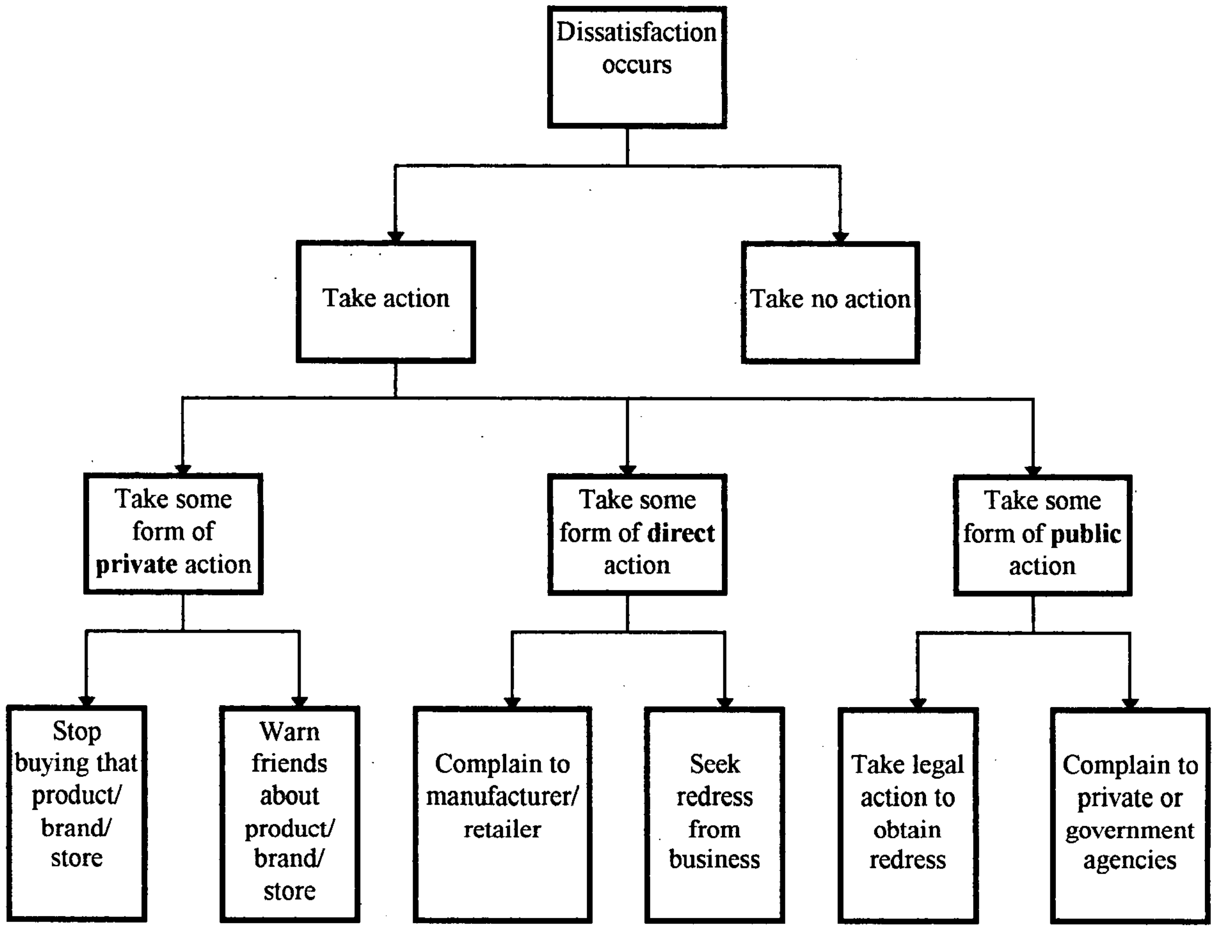


Fig. 5. Actions taken by consumers in response to product dissatisfaction (Hawkins *et al.*, 1994).

1.4 PREVIOUS STUDIES

Insects commonly associated with stored foods are known as 'stored-product insects'. These insects are most commonly coleopteran or lepidopteran species, although species from the orders Thysanura, Dictyoptera, Orthoptera, Dermaptera, Psocoptera, Hemiptera, Hymenoptera, Diptera and Siphonaptera may also be found in foods storage environments either scavenging on produce and debris, or as predators or parasitoids of other insect species present (British Museum (Natural History), 1980). Due to the economic significance of stored-product insects, their biology has generally been well investigated and documented, and therefore will not be discussed here. Hill (1990) summarises the pest status, distribution and life history of most important stored-product insects.

1.4.1 Methods of controlling stored-product insects in food processing and storage environments

Much research has been undertaken into methods of controlling stored-product insects, particularly in bulk storage environments where insect damage can be extremely damaging. Many studies have also been carried out in food processing plants and packaged commodity storage environments. Generally, methods used to control stored-product insects can be broadly classified as either physical, chemical or biological control. These methods of control are reviewed below, although the literature cited is generally restricted to studies concerning the control of lepidopteran stored-product insects in food production and storage environments, and the review is by no means comprehensive.

(i) Physical control

(a) Hygiene

The important role that appropriate hygiene practices play in the prevention and control of insect pests in processing and storage environments is well recognised throughout the food industry. Any recognised text on quality management in food handling areas will stress the importance of appropriate hygiene standards with regard to preventing pest infestations (e.g. Troller, 1983). The importance of appropriate hygiene standards has long been recognised by the confectionery industry. A booklet published by the Cocoa, Chocolate and Confectionery Alliance (Anon., 1969) emphasises the importance of good hygiene to control insect pests, and rightly states that reliance on other methods of control in the absence of good hygiene will ultimately prove ineffective. This booklet contains much information on insect infestation control still relevant today, including notes on insect control within confectionery plants, appropriate building and machinery design, handling, storage and packaging of ingredients, and handling of finished goods. Recommended cleaning regimes, appropriate equipment and methods required clean specialised machinery, and measures to aid cleaning practices are all discussed in relation to insect pest control within confectionery factories. Previous studies have shown how limiting the food supply can reduce stored-product pest populations in warehouse environments (e.g. Sower and Whitmer, 1977), while the findings of Hagstrum and Stanley (1979) emphasise the need to thoroughly clean storage warehouses.

(b) Temperature regulation

The maintenance of low temperatures in storage and production environments acts to retard insect pest development. Being poikilotherms, insect development, reproduction and other life processes are intimately influenced by temperature. The relationship between stored product insect development and temperature has been well researched (e.g. Bell, 1975; Burges and Haskins, 1965; Coombs, 1978; Howe, 1960, 1967; Imura and Nakakita, 1984; Jacob and Fleming, 1989, 1990; Johnson *et al.*, 1995; Lamb and Loschiavo, 1981; Porter, 1986). At temperatures are below 15°C, most insect pests will become inactive and may eventually die (Mullen and Arbogast, 1984).

(c) Trapping

Insect traps are generally used to detect the presence of insect pests, and monitor populations, rather than actively suppress populations. While light traps have been shown to be effective to capture lepidopteran pests (Cline and Keever, 1984; Soderstrom, 1970), synthetic pheromones are now most widely used to attract lepidoptera to traps hung in food storage and processing environments. Pheromones are commercially available for a wide range for stored-product insects, not just lepidoptera (see Phillps, 1994), and many examples of successful monitoring studies using pheromone-baited traps have been published (Hoppe and Levinson, 1979; Levinson and Buchelos, 1981; Mullen *et al.*, 1991; Šifner *et al.*, 1983; Vick *et al.*, 1986). Other features of a trap that influence its attractiveness to insect pests including its shape (Levinson and Hoppe, 1983; Quartey and Coaker, 1992; Šifner *et al.*, 1983), colour (Quartey and Coaker, 1992), and the height at which it is placed (Ahmad, 1987; Cline and Keever, 1984; Vick *et al.*, 1986).

While pheromone trapping has been used primarily to detect and monitor stored-product insects, there have been attempts to control lepidopteran populations by mass trapping. Despite theoretical doubts about the effectiveness of this strategy (Birch and Haynes, 1982), apparent preconditions for effectiveness (Burkholder and Ma, 1985), and poor methodology (Phillips, 1994), there have been a number of studies that claim to have successful suppressed populations via this method (Pierce, 1994; Šifner *et al.*, 1983; Süss and Trematerra, 1986; Trematerra and Bataini, 1987). Both Burkholder and Ma (1985) and Phillips (1994) have recently reviewed the literature concerning use of pheromones to monitor and control stored-product insects.

(ii) Chemical control

(a) Pesticides

Public concerns over the potentially harmful effect of chemical residues in food (e.g. Danse *et al.*, 1984), has led to a preference for controlling stored-product pests through non-chemical means. Insect resistance to a range of fumigants and other pesticides has also necessitated a shift away from chemical control methods. Champ and Dyte (1976) found that stored grain pests from many countries were resistant to a number widely used chemical control agents, and later studies have continued to reveal resistance to many pesticides in stored-product pests (e.g. Attia, 1976; Keever *et al.*, 1986). Consequently, the use of 'natural', non-residual pesticides, such as pyrethrum, has become more common, although insect resistance to synergised pyrethrins has also been reported (e.g. Cline *et al.*, 1984; Meyer *et al.*, 1990). The application of pesticides can also detrimentally affect non-target, beneficial species

(Keever *et al.*, 1986). Banks (1994) recently reviewed the current status and future prospects of fumigant technology.

(b) Insect growth regulators

Siddall (1976) defined an insect growth regulator (IGR) as "a substance which acts within an insect to accelerate or inhibit a physiological regulatory process essential to the normal development of an insect or its progeny, in such a way that the action of the substance is necessarily dependant on the life stage of the insect". The IGRs that have attracted most attention are juvenile hormone analogues which mimic natural juvenile hormones and, when insects are exposed to them, produce a range of novel biological effects. For instance, applications of the juvenile hormone analogue methoprene prevents metamorphosis of the almond moth *Ephestia cautella*, possibly by inhibiting the production of ecdysone which is a hormone that induces moulting and subsequent cuticle deposition (Shaaya and Pisarev, 1986). Methoprene has been found to successfully suppress *E. cautella* populations (Nickle, 1979; Vick *et al.*, 1985). An advantage of using IGRs rather than conventional pesticides is that they are relatively specific; insect juvenile hormones appear to be confined solely to insects and, therefore, they will act only on insects (Siddall, 1976). They apparently have very low mammalian toxicity and persistent residues mean that effective control can be maintained over long periods (Nickle, 1979; Vick *et al.*, 1985).

(c) Mating disruption

Disruption of mating can be facilitated by continually broadcasting high concentrations of female sex pheromones into an environment. Mating may be affected in either of three ways: male responsiveness to females may decrease as a result of adaptation or habituation of the central nervous system; high level background pheromone concentration may result in males being unable to locate receptive females; or certain pheromone components may block mating response (Tette, 1974). Studies examining the utility of this method of control have produced mixed results with Brady *et al.* (1975) finding that lepidopteran pest populations were not suppressed by this method, while Sower and Whitmer (1977) and Hodges *et al.* (1984) found the opposite. As with mass trapping, a low initial population density appears to be a precondition for the successful application of this method of control (Sower and Whitmer, 1977).

(iii) Biological control

(a) Parasitoids

Parasitoids are insect parasites whose larval stage occurs either partly or wholly within the host, feeding on the hosts internal tissues, resulting in the death of the host. Hymenopteran parasitoids such as have been found to effectively control lepidopteran populations within commercial warehouses. For example, the small parasitic wasp *Bracon hebetor* has been found to be highly effective in suppressing populations of *E. cautella* either alone (Cline and Press, 1990; Nickle and Hagstrum, 1981), in combination with *Trichogramma pretiosum* (Hymenoptera: Trichogrammidae) (Brower and Press, 1990), or in combination with predators (Keever *et al.*, 1986). The parasitic wasp *Venturia canescens* has also been shown to suppress stored-product lepidoptera (Cline *et al.*, 1986).

(b) Predators

Predators of stored-product insect can potentially regulate pest populations, although difficulties in distributing the predator, and maintaining viable populations, make this method of control impractical in some storage environments (Haines, 1981). The warehouse pirate bug *Xylocoris flavipes*, when used in combination with *B. hebetor* can suppress stored-product lepidoptera (Keever *et al.*, 1986), while the ascid mite *Blattisocius tarsalis* is recorded as a predator of many stored product insects (Haines, 1981). *Lyctocoris campestris* (Heteroptera: Anthocoridae) is also considered to be a potentially suitable biological control agent in stored product environments due to its adaptability to mass rearing conditions, predatory ability, and its apparent broad range in prey species and size (Parajulee and Phillips, 1994).

1.4.2 Prevention of infestation of packaged goods by stored-product pests

By comparison with the copious literature concerning the biology, detection and control of stored product insects in food production and storage environments, there has been relatively little attention paid to the prevention of insect contamination of packaged foodstuffs. Of the studies that have been conducted, most have concentrated on the preventative role played by packaging materials.

Stored-product insects that invade packaged goods are broadly categorised as either 'pentrators,' if they are capable of boring through packaging materials, or 'invaders' if they can only enter through existing openings (Highland, 1984). Studies examining the resistant properties of various types of packaging materials have shown that penetrators (and sometimes invaders) can pierce most flexible polymer films as well as foil, paper and laminates (Batth, 1970; Cline, 1978; Gerhardt and Lindren, 1954, 1955; Highland and Jay, 1965; Highland and Wilson, 1981; Highland *et al.*, 1968; Rao *et al.*, 1972; Yerington, 1975). Some materials offer better resistance against penetrators than others (e.g. Cline, 1978), while the thickness (Highland, 1984) and form (e.g. whether polypropylene is biaxially-orientated or non-orientated (Yerington, 1975)) of materials can also influence the likelihood of penetration.

The integrity of packaging is equally as important as the packaging material itself, and sometimes more so (e.g. Mullen and Highland, 1988). Penetrators, as well as invaders, will invade goods through pre-existing openings (Mullen and Highland, 1988) resulting in a direct correlation existing between package seal quality and the extent and swiftness of infestation (Mullen and Highland, 1988; Yerington, 1978). Some invaders can enter through holes of less than 2mm diameter (Cline and Highland, 1981) while newly hatched larvae are able to enter much smaller holes (Mullen and Highland, 1988).

Another approach to preventing insect contamination of packaged goods has been to treat packaging materials with pesticides. Highland and Cline (1986) and Highland *et al.* (1986) found that by treating packaging materials with permethrin, insect penetration can be prevented for considerable periods of time, although the spatial and temporal proximity of chemicals to products destined for human consumption makes such practices potentially hazardous (Highland, 1984).

As well as preventing insect invasion, packaging techniques can be used to kill insects that are accidentally packaged with goods. This is most common attempted by using vacuum packing, although this technique has provided mixed results with success depending on the type of film used and the maintenance of package integrity (Cline and Highland, 1987; Highland, 1988; New and Rees, 1988). The rigid configuration of vacuumised packs may also make them more susceptible to penetration externally (Highland, 1988). Flushing packages with inert gases may provide a more practical method of eliminating infestations (New and Rees, 1988).

While packaging obviously plays an important role in the prevention of insect contamination, there are apparently many other elements that influence the infestation of packaged goods, although these have been little explored. Both Anon. (1969) and Highland (1984) list a number of contributing factors, although no specific quantitative references are cited. Both authors observe a relationship between the likelihood of infestation and temperature/season/climate: packaged goods stored in warm warehouses are more likely to be infested than goods stored in cooler warehouses; infestation cases increase as summer progresses and; geographical location influences the likelihood of infestation (i.e. as one moves closer to the equator, the incidence of infestation greatly increases). Given the reliance of insects on warm conditions for growth and development, such observations are not surprising. The composition of foodstuffs is also important, with some foods more likely to become infested than others (Highland, 1984), and the length of time goods are stored is also influences the likelihood of infestation (Anon., 1969; Highland, 1984).

While there are obviously many factors that can influence whether packaged goods become contaminated by stored-product insects or not, the primary factor is exposure to the pests in the first place, and, has already been mentioned, good hygiene conditions are fundamental to achieving an insect-free environment. Cleanliness in all storage, transport and display environments is vitally important to insure against product contamination post-packaging (Anon. 1969).

There appears to have been little research undertaken to investigate the actual insect invasion processes. Highland (1984) suggests that "infestation probably is a consequence of searching, exploratory activities of the insects, and the subsequent discovery of food that is suitable for nourishment and reproduction", although whether these activities are determined primarily by chance, or whether environmental cues are involved, is not known.

1.4.3 Research undertaken in this study

In order to gain a broad understanding of the possible factors that influence the insect infestation of chocolate-based consumables, this study set out to investigate and quantify some of the less well researched areas mentioned above: company consumer complaint databases were analysed to investigate how factors such as geographic location, product age, time of product manufacture, and point of sale influenced the likelihood of infestation; surveys of insect pests were conducted at points along the manufacture and distribution network to shed light upon the origins of infestation and; studies were undertaken to examine some aspects of stored-product pest ecology with regard to post-packaging infestation.

In addition, some of the better understood factors that influence both post- and pre-packaging infestation were also investigated. The insect resistant properties of packaging materials, and the degree to which package integrity influences the likelihood of infestation, were both examined. Also, extensive trapping studies to detect, monitor and control insect pests resident at the Claremont plant were also undertaken.

By drawing together many of the diverse elements that influence the infestation of chocolate-based consumables manufactured at the Claremont plant, it was hoped that a relatively complete picture of the problem could be composed, so that practical, effective measures to minimize the insect contamination could be identified.

CHAPTER 2

Analysis of infestation-related consumer complaint databases

2.1 INTRODUCTION

There are an enormous variety of factors that potentially influence whether a product manufactured at Claremont will be infested. For example, the composition of a product (Highland, 1984), the type of packaging used (e.g. Cline, 1978), the integrity (wholeness) of the packaging (Mullen and Highland, 1988; Yerington, 1978), the conditions under which it's stored (Anon., 1969), the period of storage (Highland, 1984; Anon., 1969), the location of the retail outlet from which it is sold (Highland, 1984; Anon., 1969), may all, to some degree, influence the likelihood of exposure to insect pests and subsequent infestation. One way to access the importance, or otherwise, of some of these factors is to analyse information contained on consumer complaint databases.

Every consumer complaint received by the company is recorded on computerised databases. Information generally recorded includes: details of the complainant; the date the complaint was received; the type of product; its date-code; the type of complaint and, the outlet from which the item was purchased. Consequently, much can be learnt about the infestation problem simply by analysing these databases. However, in order to produce meaningful results, it is essential that infestation consumer complaints accurately reflect the general occurrence of infestation in the marketplace. A consumer quality survey conducted by Sensory Market Analysis and Research Technology (SMART) in 1992 found that 68% of consumers would contact the relevant company if they purchased a product containing foreign matter (eg. sticks or hair). Presumably, a higher percentage would contact the company if they purchased an infested product, due to the more offensive nature of the fault. Therefore, it is believed that a sufficiently high proportion of infestation occurrences are reported to the company for an analysis of the consumer complaint databases to produce meaningful results.

By analysing information contained in the consumer complaint databases, it was hoped that products typically at risk of infestation could be identified and strategies to minimise infestation could be formulated. In addition, by using the databases to help quantify the costs associated with infestation, it was hoped that economic parameters could be defined, against which strategies to minimise infestation could be costed.

2.2 MATERIALS AND METHODS

2.2.1 Distribution of infestation complaints between product groups and states

Only Cadbury Schweppes products manufactured at the Claremont plant and sold domestically between 1990 and 1994 were included in the analysis. The number of complaints, sales volume, and complaint rate (complaints per tonnes sold) of each product type sold during the years 1990-1994 is shown in Appendix I.

Two assumptions are implicit in this analysis. Firstly, it was assumed that items were purchased in the same state from which the complaints originated and, secondly, that the retail cost of a product did not influence the likelihood of a complaint being registered by consumers.

The data from the 'food', 'children's', 'pic-n-mix' and 'self' groups were pooled into a category named 'other' due to the low number of complaints received concerning these product types.

Analysis of the geographical distribution of complaints concerning individual products was limited to products for which at least 20 complaints per year were received, and due to insufficient data, complaints from Tasmania were excluded.

Analysis of the complaint rate trend for individual assortment products was limited to lines for which >150 complaints were received over the 5 year period. Data from the two territories was excluded due to the non-availability of sales figures.

The transformed (sqrt(x+1)) complaint rate was used for analysis of variance calculations, and Tukey's test was used to compare non-identical means (Zar, 1984).

2.2.2 The 'age' and date of manufacture of infested product

At the time of manufacture, most products are stamped with a date code to inform consumers of when the recommended use-by period expires. Most produce manufactured at Claremont for domestic sale has a use-by period of 52 weeks. Therefore, the date stamped on product is generally the date 1 year in advance of the date of manufacture. Consequently, if date code details were supplied by the consumer, the date of manufacture of infested produce was able to be readily calculated. The 'age' of infested product was determined by calculating the period between the date of manufacture and the date the consumer complaint was received by the company. Again, only Cadbury Schweppes products manufactured at the Claremont plant and sold domestically between 1990 and 1994 were included in the analysis.

Upon calculating the 'date of manufacture' details, an error in the database was detected. According to the database, of the infestation complaints lodged with the company in 1990, concerning product manufactured in 1989, almost half (46%) of these products were manufactured in a single month (October, 1989), and, of these, almost all (86%) were apparently manufactured in a single week (the first week of October). Further investigation revealed that these complaints were distributed among 6 moulded product lines and 27 assortment lines. While the factory has the capacity to manufacture 6 moulded lines in a single week, it does not have the capacity to manufacture 27 assortment lines. The factory manufactures a maximum of 5 or 6 assortment lines a week (B. Brassington *pers. comm.*). Therefore, all of these products could not have been manufactured during the same week. An error has occurred either in the date-coding of these products, or during the collation of the database. Therefore, all products manufactured in 1989 data were excluded from 'age' and 'date of manufacture' analyses. This error did not affect any of the other results presented.

2.2.3 Retail outlets from which infested product was purchased

Cadbury produce is sold at a wide variety of retail outlets that are broadly classified into 2 categories: the 'traditional' retail sector, comprising small, independent retail outlets such as milk bars and delicatessens and; the 'grocery' retail sector, which comprises the corporate supermarket chains. The traditional retail sector accounts for 42.4% of sales, and the grocery sector 57.6% (Cadbury Schweppes Pty. Ltd, 1995). These proportions were used to calculate the 'expected' values for chi-squared analysis examining whether the number of infestation-related complaints from goods purchased from each sector was dependent upon the sales made by each sector. This analysis only included retail outlets from which infested stock was purchased from

January 1994 to July 1995. Appendix II lists each infested item as well as the retail outlet from which it was purchased [Note: only produce manfactured at Claremont was included in the analysis; compare with Appendix I].

2.2.4 Costs associated with infestation

When assessing the cost to the manufacturer of a quality fault, there are two classifications into which costs can generally be divided; 'avoidable' costs, which are those costs directly attributable to a quality fault, and 'unavoidable' costs, which are associated with strategies aimed at minimizing the occurrence of quality defects during manufacture (Juran and Gryna, 1970). Only the avoidable costs are presented here (the unavoidable costs are presented in Chapter 6). The avoidable costs were divided into four categories: lost sales, reimbursement, labour and postage.

Lost sales were calculated on the basis of a recent consumer quality survey (SMART, 1992) which found that, on average, for every complaint received by a manufacturer, at least 8 consumers will stop buying a product and the company will never hear from them. Lost sales were therefore calculated by multiplying the recommended retail value of every item, for which there was an infestation complaint, by a factor of 8. The retail values of individual products, as of March 1995, are listed in Appendix III [Note: not all products listed in Appendix III are manufactured at Claremont; compare with Appendix I, which lists those that are].

Reimbursements were calculated in accordance with Cadbury Schweppes' Sales Executive Reimbursement Policy (Appendix IV). The 'pic'n'mix' product group was not included in the reimbursement policy, so the reimbursement costs for these products were unable to be calculated.

Postage costs for 1991 were obtained from Cadbury Schweppes' Consumer Services department (Ringwood, Victoria). Postage costs for the other years were calculated on a proportional complaint basis.

Consumer complaints are processed at both Claremont and the company's other domestic manufacturing plant located in Ringwood (Victoria). The labour associated with processing infestation complaints at Ringwood in 1991 were also obtained from Cadbury Schweppes' Consumer Services department. Labour costs for the other years were calculated on a proportional complaint basis. The labour costs associated with processing infestation complaints at Claremont was calculated on an estimate by the Quality Control officer responsible that 15% of his time was spent processing infestation complaints (annual income of officer ~ $30,000) in 1991 (G. D'louhy *pers. comm.*). Labour costs for the other years were calculated on a proportional complaint basis.

2.3 RESULTS

2.3.1 Distribution of infestation complaints between product groups and states

The analysis revealed that there was a significant difference in: the infestation complaint rate per year; the distribution of complaints between product groups; the distribution of complaints between states; the number of complaints between product groups per year and, the number of complaints between product groups per state. There was no significant difference in the complaint rate between states per year (Table 1). These results are discussed separated below.

Table 1. Analysis of variance of the transformed (sqrt(x+1)) infestation complaint rate (complaints per tonne sold) between product groups (assortments, bars, moulded and other) and states (New South Wales, Queensland, South Australia, Victoria, Western Australia and Tasmania) from 1990 to 1994. A - year, B - product groups, C - states, *** - P<0.001, ns - not significant.

Factor(s)	*df*	ms	*F*
A	4	0.0044	9.47***
B	3	0.1017	220.37***
C	5	0.0077	16.61***
A x B	12	0.0043	9.29***
B x C	15	0.0042	9.00***
A x C	20	0.0005	1.06ns

(i) Year

There was a significant decrease in the number of complaints from 1990 to 1994 despite an increase in overall sales (Table 2). In 1994, there were 853 fewer complaints received than in 1990. The most significant decrease in the number of complaints occurred in 1992, when complaints decreased 52% from the previous year. Following 1992, the number of complaints remained at a level consistently well below those recorded in 1990 and 1991. The complaint rate indicated the extremely low incidence of infestation, with only 3 - 7 complaints received for every 100 tonnes of product sold.

Table 2. Total number of infestation complaints and product sales.

Year	Complaints	Sales (t)	Complaint rate (complaints/sales)
1990	1727	26441	0.065
1991	1581	25419	0.062
1992	759	27708	0.027
1993	1018	28963	0.035
1994	874	28557	0.031

(ii) Product groups

As a proportion of sales, assortment products were significantly more susceptible to infestation than non-assortment products (Fig. 1). Assortments also exhibited considerable variation in the complaint rate. By contrast, the complaint rate for non-assortment product groups remained at constantly low levels.

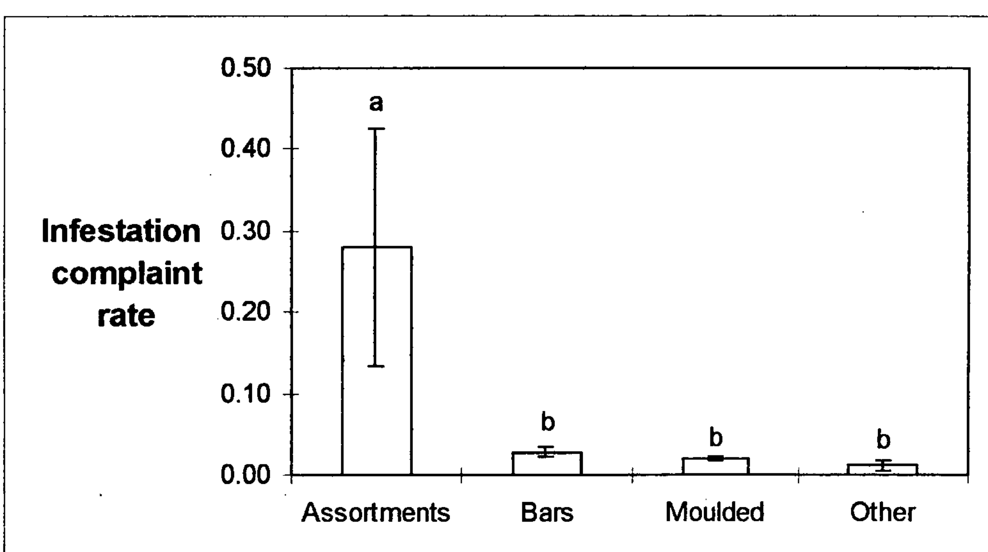


Fig. 1. The mean (±SD) infestation complaint rate (complaints per tonne sold) per product group (1990 -1994). Mean complaint rates for each product group with the same letter are not significantly different at the 5% level of probability (Tukey test).

(iii) States

Significantly more infestation complaints were received from WA than all other states except QLD (Fig. 2). There was no significant difference in the rate of complaints from NSW, QLD, SA and VIC. TAS had the lowest complaint rate although it was not significantly different from SA and VIC.

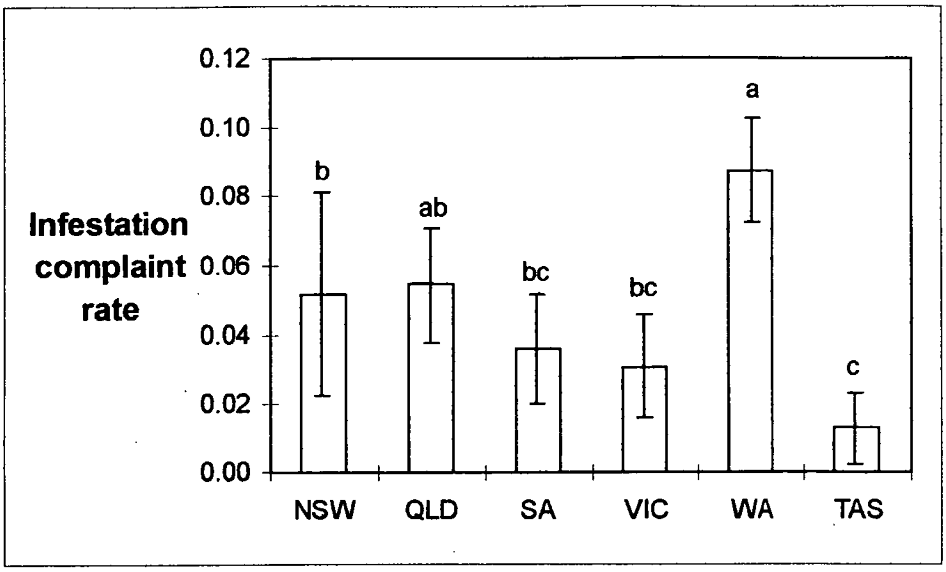


Fig. 2. The mean (±SD) infestation complaint rate (complaints per tonne sold) per state. Mean complaint rates for each state with the same letter are not significantly different at the 5% level of probability (Tukey test). The states included for analysis were New South Wales (NSW), Queensland (QLD), South Australia (SA), Victoria (VIC), Western Australia (WA) and Tasmania (TAS).

The mean complaint rate of each state was strongly correlated (r = 0.83) with the average yearly maximum temperature of each state capital (Bureau of Meteorology, 1988) indicating that the distribution of infestation complaints is temperature dependent.

At the individual product level, the geographical distribution of complaints was not consistently temperature dependent. While commonly infested (≥ 20 complaints per year) products showed a significant difference in the rate of complaints between states (Table 3), only the distribution of assortment products, perhaps with the exception of 250g Milk Tray, was temperature-dependent (Fig. 3). The distribution of complaints concerning non-assortment products (250g Hazel Nut Milk and 30g Flake) showed only a weak dependence on temperature. In common with the distribution of complaints at the product group level, all products had a high rate of complaints from WA, particularly 250g Milk Tray and 250g Hazel Nut Milk, which both had a significantly higher rate of complaints rate from WA than any other states (Fig. 3). The assortment products 250g and 500g Roses, and 500g Milk Tray also had high rates of complaint from QLD, although 250g Milk Tray did not.

Table 3. Analysis of variance of the transformed (sqrt(x+1)) infestation complaint rate (complaints per tonne sold) between states for individual products (* - P<0.05, ** - P<0.01, *** - P<0.001, ns - not significant).

Product Group	Product	Complaints (1990-1994)	*df*	ms	*F*
Assortments	250g Milk Tray	508	4	0.0365	9.30***
	500g Milk Tray	251	4	0.0104	3.79*
	250g Roses	501	4	0.0081	4.98**
	500g Roses	206	4	0.0066	6.95**
Moulded	250g Hazel Nut Milk	172	4	0.0007	5.71**
Bars	30g Flake	155	4	0.0013	3.79*

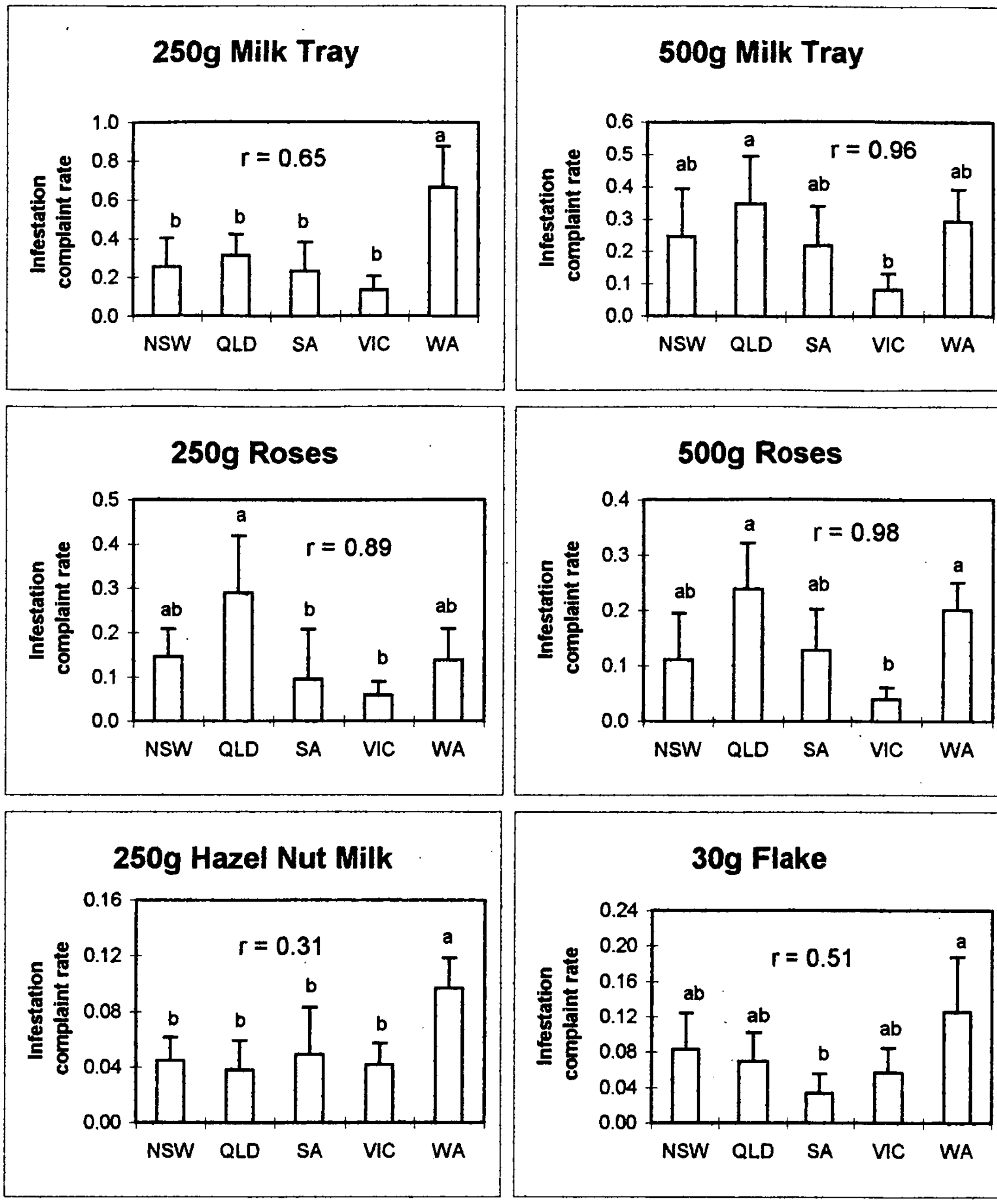


Fig. 3. The mean (+SD) infestation complaint rate (complaints per tonne) per state for individual products. Mean complaint rate for each state with the same letter is not significantly different at the 5% level of probability (Tukey Test). The correlation coefficient (r) indicates the degree of dependence of the mean complaint rate of each product per state (1990-1994) on the average yearly maximum temperature (°C) in the capital city of each state. The states included for analysis were New South Wales (NSW), Queensland (QLD), South Australia (SA), Victoria (VIC) and Western Australia (WA).

(iv) Product groups per year

The significant difference in the number of complaints received for each product group each year was primarily due to a decrease in the rate of assortment complaints (Fig. 4). In 1994, 843 fewer complaints were received than in 1990, a decrease of 67%. As with the trend in the overall complaint rate (Table 1), the number of complaints decreased markedly in 1992, and these lower levels were sustained during 1993 and 1994. As a consequence of the remarkably constant complaint rate of non-assortment product groups, yearly variation in the total complaint rate (all product groups) was almost entirely dependent upon variation in the assortment complaint rate ($r^2 = 0.98$; Regression ANOVA: $F = 146.368$, $df = 4$, $P<0.05$).

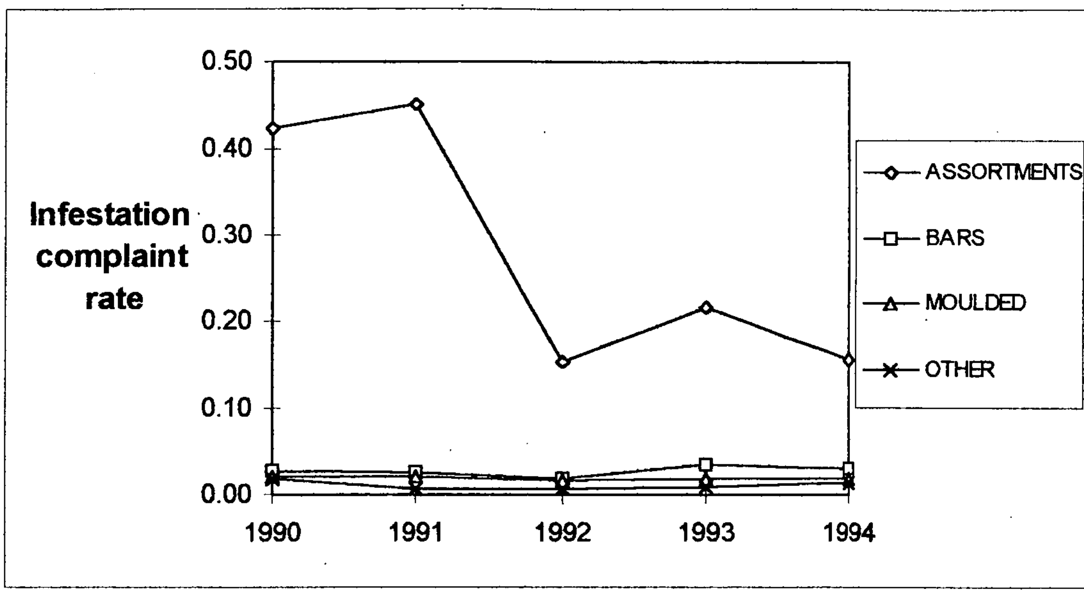


Fig. 4. Infestation complaint rate (complaints per tonne sold) per product group per year.

Variation in the yearly complaint rate was not uniformly exhibited amongst commonly infested (>150 complaints from 1990 to 1994) individual assortment products, although most did demonstrate an overall decline in the complaint rate (Fig. 5). Two products (250g Hazelnut Whirls and 250g Roses), by contrast, showed an increase in the rate of complaints from 1990 to 1994.

The decline in the complaint rate of a number these products (250g Black Cat, 250g Dark Favourites, 250g Cabaret) is believed to have been significantly influenced by a decline their manufactured output. Appendix I clearly reflects the decline in manufacture through declining sales figures. In 1990, these three products represented

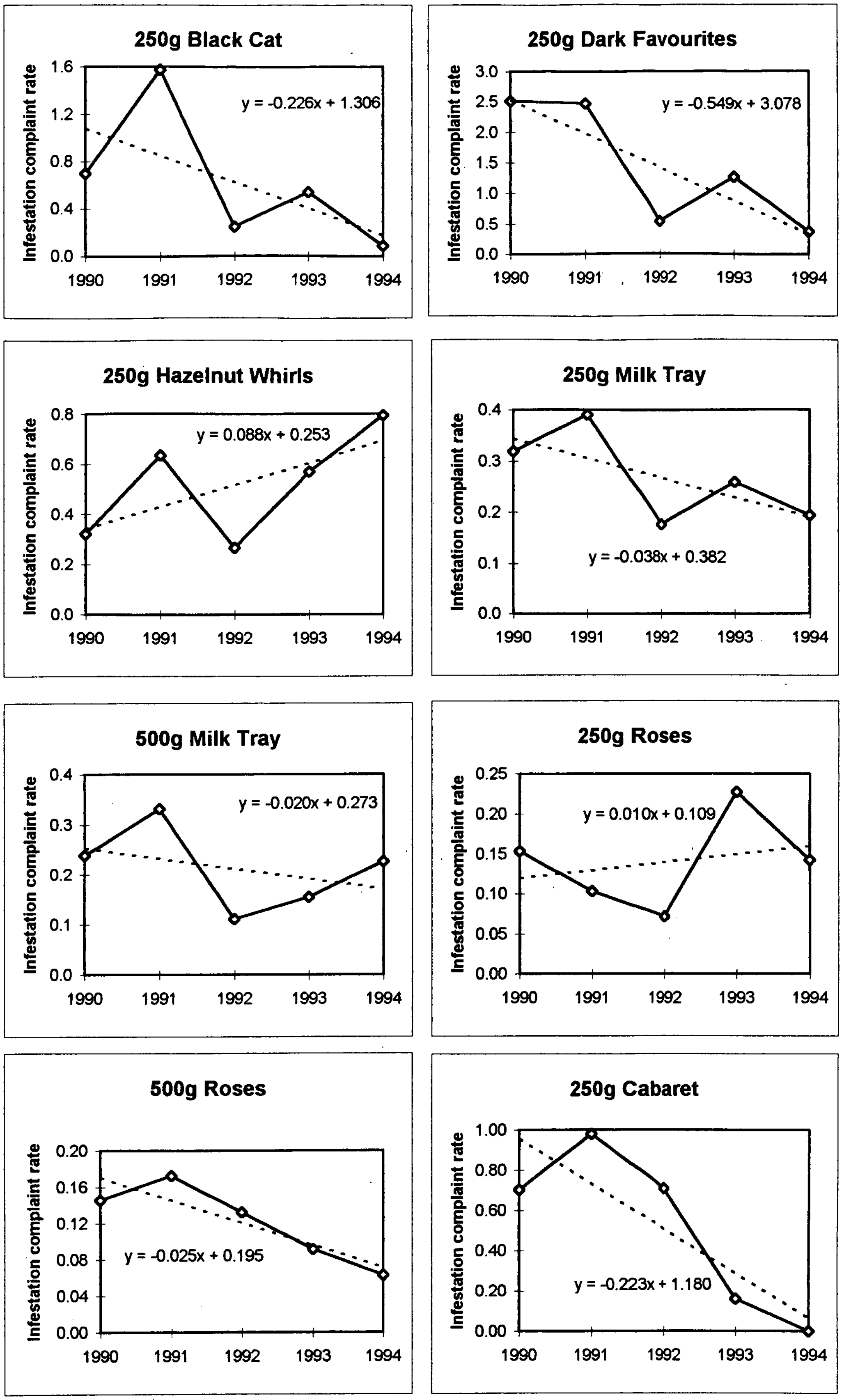


Fig. 5. Infestation complaint rate (complaints per tonne sold) for individual assortment products. The dashed line and associated equation represent the complaint rate trend of each product.

11% of all assortments sold, but by 1994, they contributed only 0.4% of sales. Therefore, the decline in the overall complaint rate has been due, to some extent, to the reduced apparency of these highly susceptible products in the marketplace.

(v) Product groups per state

The distribution of complaints between product groups at the national level (Fig. 2) was mirrored in all states (Fig. 6). Despite minor variations between the states, the assortment complaint rate was consistently higher than the non-assortment complaint rates. The assortment complaint rate also exhibited a high degree of variation in each state. In contrast, the complaint rate of non-assortment product groups remained at consistently low levels. Therefore, as a proportion of sales, assortment products were more susceptible to infestation in all Australian states. Infestation complaint rates across all product groups were highest in WA.

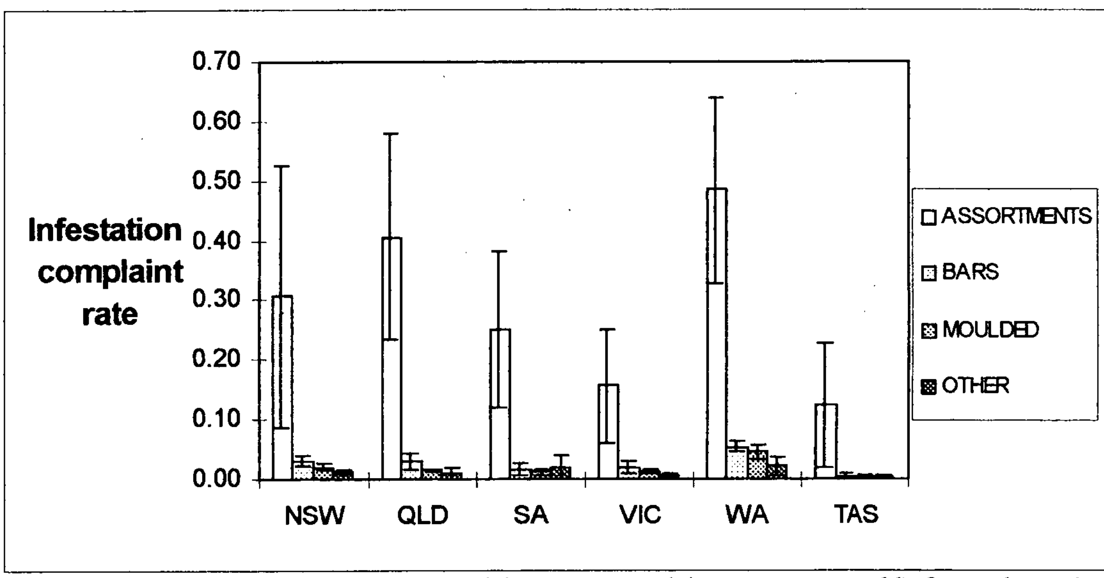


Fig. 6. The mean (±SD) infestation complaint rate (complaints per tonne sold) for each product group per state (1990-1994). The states included for analysis were New South Wales (NSW), Queensland (QLD), South Australia (SA), Victoria (VIC), Western Australia (WA) and Tasmania (TAS).

(vi) States per year

There was no significant difference in the rate of infestation complaints originating from each state each year. As variations in the overall complaint rate were principally determined by variations in the rate of infestation of assortment products (see section iv), this result suggests that the assortment complaint rate in each state also varied in a uniform fashion each year. As shown in Fig. 7, this was the case, with uniformity particularly apparent after 1991.

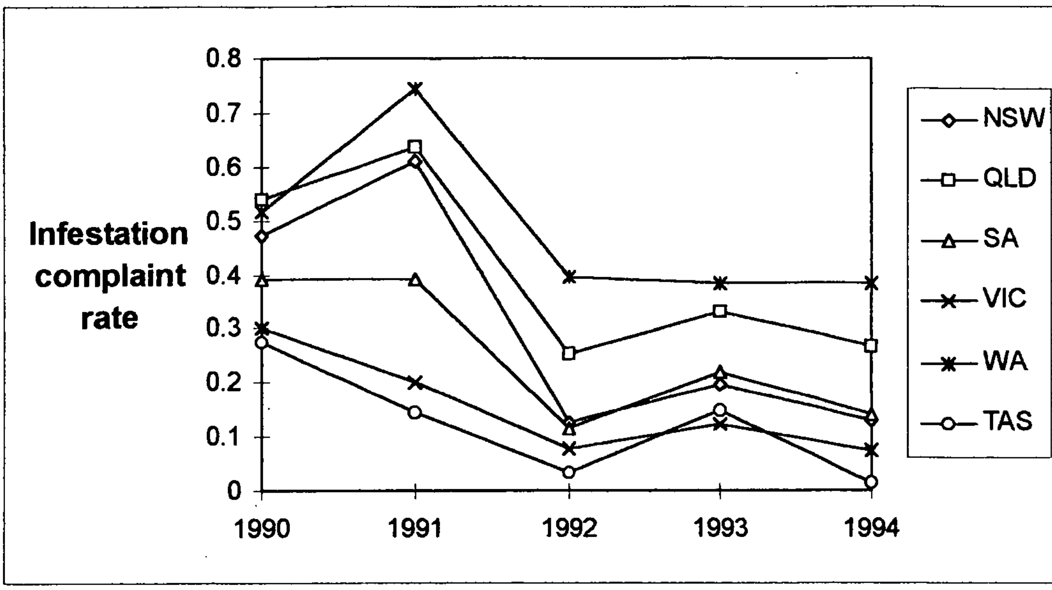


Fig. 7. Infestation complaint rate (complaints per tonne sold) of assortment products in each state per year. The states included were New South Wales (NSW), Queensland (QLD), South Australia (SA), Victoria (VIC), Western Australia (WA) and Tasmania (TAS).

2.3.2 The 'age' of infested product

It was found that the 'age' (or length of time between manufacture and receipt of complaint by the company) of infested product was considerable. The average age of infested goods was ~9 months (Table 4). The longest period between manufacture and complaint was recorded for assortment products, while bars had the shortest period. The use-by date on 16% of products had expired by the time the complaint was received. Produce of this age (7-10 months) are regarded as 'old' stock by the company, as stock is usually sold well before it reaches this age (R. Berry *pers. comm.*). Therefore, old stock is most susceptible to insect infestation.

Table 4. The 'age' (length of time between manufacture and sale) of infested products. Includes complaints received during 1990-1994 excluding products manufactured in 1989. n - number of infestation-related consumer complaints.

PRODUCT GROUP	n	$\bar{x}$ (days)	SD (days)
Assortments	2127	281	96
Bars	123	215	89
Moulded	733	255	116
Other	10	254	150
Total	2993	272	103

2.3.3 Date of manufacture of infested product

When the date of manufacture of products that were the subject of infestation-related consumer complaints was calculated, a cyclical trend became evident (Fig. 8). The cycle began around May/June, peaked from September to November, and finished around April/May the following year. This indicated that produce manufactured in Spring (September- November) was most likely to be infested.

However, it must be recognised that production at Claremont is also cyclical; more goods are manufactured at certain times of the year than others. Therefore, the trend in Fig. 8 is dependent, to some degree, on fluctuations in the production schedule of the factory. Correlation analysis was undertaken to determine the degree to which the 'date of manufacture' of consumer complaints (1990 - 1994) involving 4 assortment products (250g, 500g Roses and 250g, 500g Milk Tray) was dependent upon their production schedules (quantity (kg) of product manufactured (every 4 weeks 1990-1993)). It was found that there was only a moderate correlation between the quantity of stock produced at a certain time, and the subsequent number of complaints received concerning that stock (Table 5). Therefore, while the date of manufacture of infested goods is, to some degree, dependent upon production schedules, seasonal factors are also important.

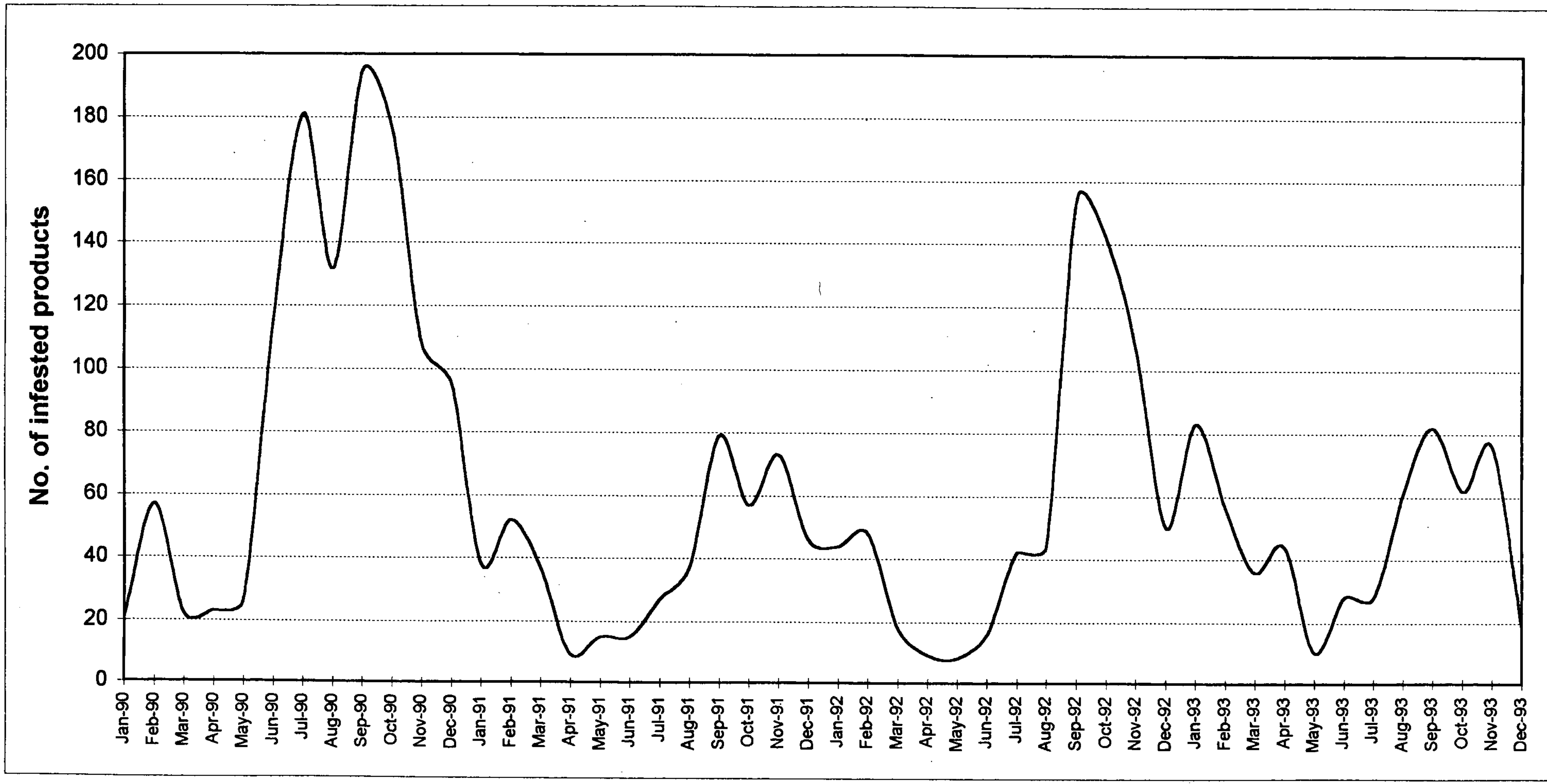


Fig. 8. The date of manufacture of produce the subject of infestation-related consumer complaints.

Table 5. Correlation between the quantity (kg) of product manufactured (every 4 weeks 1990-1993) and the number of infestation-related consumer complaints subsequently received concerning this product. r - correlation coefficient.

PRODUCT	r
250g Roses	0.55
500g Roses	0.59
250g Milk Tray	0.59
500g Milk Tray	0.62

2.3.4 Retail outlets from which infested products were purchased

Infested product was purchased in almost equal proportions from the two retail sectors, 'traditional' and 'grocery' (Table 6). Chi-square analysis, however, revealed that, on the basis of sales, this represented a significantly higher proportion of complaints from the traditional sector than expected. Therefore, produce sold through traditional retail outlets is significantly more likely to be infested than that sold through the grocery sector.

Table 6. Proportion of infested goods purchased from each retail sector from January 1994 to July 1995. The 'expected' values represent the proportion of sales made by each sector (Cadbury Schweppes Pty. Ltd, 1995).*** - P<0.001.

Retail sector	Complaints	% (actual)	% (expected)	$\chi^2_{(0.05,1)}$
Traditional	248	50.2	42.4	12.31***
Grocery	246	49.8	57.6	
Total	494			

2.3.5 Additional factors

The composition of products appears to influence the likelihood of infestation, and this is most obvious when comparing the infestation rates of various moulded block products (Appendix I). Products containing either nut (e.g. Hazel Nut Milk, Nut Mix) or nut and dried fruit ingredients (e.g. Fruit and Nut Milk, Rocky Road) generally had a higher rate of infestation than products containing only fruit ingredients (e.g. Old

Jamaica, Black Forest), and these, in turn, generally had higher infestation rates than products comprised of only chocolate (e.g. Dairy Milk, Premium, Energy). The variety of nut contained in a product also appears to influence the likelihood of infestation; Hazel Nut Milk products (containing hazelnut pieces) generally had a higher infestation rate than products containing other nut varieties (e.g. Cashew Nut Milk, Brazil Nut Milk, Roast Almond). Whether the type of chocolate contained in a product is milk (e.g. Dairy Milk), dark (e.g. Premium, Energy) or white chocolate (e.g. Milky White) appears to have little influence on the rate of infestation. Therefore, in terms of product composition, the presence of nuts and, to a lesser extent, dried fruit ingredients, appears to heighten the risk of infestation.

There also appears to be a close relationship between the integrity of product packaging and the likelihood of insect infestation. For example, when the infestation rates of the chocolate bar products 30g Flake and 35g Twirl (Appendix I) were compared, it was clear that while the Twirl product consistently outsold the Flake product, more infestation complaints were registered against the Flake product. As ingredients that make up each product are essentially the same, the difference in infestation rates was probably due to the Flake bars being packaged with an unsealed 'twist' wrap, while the Twirl bars were completely sealed in pouches. Because of the lack of gaps, the pouch type packaging is probably more insect resistant than the twist type packaging.

A further example of how package integrity can influence infestation can be seen by comparing the infestation rates of the various Roses assortment products sold in 1994. Of each of the Roses box sizes sold (150g, 200g, 250g 500g and 750g), the 200g box size attracted the highest rate of infestation. As the variety of units in each box size is the same, the higher rate of infestation of 200g boxes was probably because all Roses boxes, except the 200g box size, were overwrapped with a polyvinyl chloride (PVC) shrink film. The absence of the overwrap probably left the 200g box more vulnerable to insect invasion.

2.3.6 Costs associated with infestation

It was estimated that the insect infestation of goods cost the company almost $½m during the years 1990 to 1994 (Table 7). Lost sales were the major component of these losses, while reimbursements also contributed a significant amount. Labour and postage were lesser costs. A decrease in the number of complaints from 1990 to 1994 (see Table 2) led to a concomitant decrease in costs. The average cost for each complaint was $83. Although only accounting for 63% of infestation complaints, assortments accounted for 86% of the costs (lost sales and reimbursements) associated with infestation (Fig. 9).

Table 7. The avoidable costs associated with the infestation of product.

COST		1990 ($)	1991 ($)	1992 ($)	1993 ($)	1994 ($)	Total ($)
Lost Sales		103 386	94 755	34 449	47 677	38 073	318 340
Reimbursement		37 670	34 598	14 099	19 257	15 959	121 583
Labour	*Melbourne*	5 684	5 200	2 080	3 328	2 860	19 152
	Claremont	4 919	4 500	1 800	2 880	2 475	16 574
Postage		5 769	5 278	2 111	3 378	2 919	19 455
Total		157 428	144 331	54 539	76 520	62 286	**495 104**
Cost/complaint		91.16	91.29	71.86	75.17	71.27	83.09

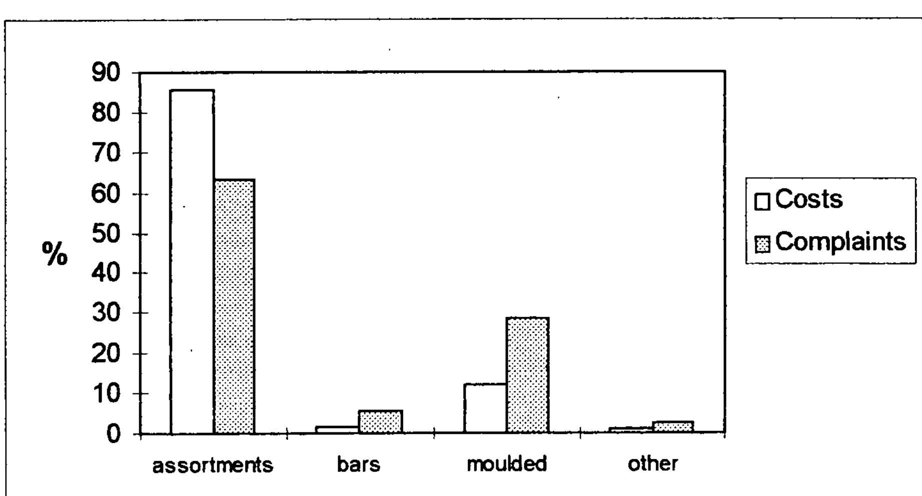


Fig. 9. Proportion of infestation complaints and costs associated with each product group.

2.4 DISCUSSION

Analysis of the consumer complaint databases have confirmed many of the observations of Anon. (1969) and Highland (1984) regarding insect infestation of packaged goods. Firstly, the length of time goods are stored clearly influences the likelihood of infestation (Anon. 1969; Highland, 1984), with the majority of infestation occurring a long time after manufacture (Anon., 1969).

The length of time that produce is stored is thought to be a significant factor in the high infestation rate of assortment products. While no data is presented to verify the following, it is generally accepted within the company that assortment products have a slower turn-over rate at retail outlets than other products, and are consequently more likely to be stored for lengthy periods (R. Berry *pers. comm.*). This is primarily due to cost and cultural factors. Expensive boxed chocolates are traditionally given as gifts on special occasions and, as such, are purchased relatively infrequently. Other products, in contrast, such as the less expensive moulded blocks and chocolate bars, are usually purchased on impulse as snack food and, consequently, are purchased more frequently. The more frequently products are sold, the faster their retail turn-over rate is and, consequently, the less time they spend in storage. The less time products are kept in storage, the less likely they are to be exposed to insect pests (Anon. 1969). Also, attractive odours are less likely to become concentrated in the headspace if stock is stored for only short periods (see Chapter 5), and actual insect damage may be less apparent.

The materials and techniques used to package assortment products was probably also a factor influencing the high infestation rate of assortments. The role that packaging plays in the infestation of assortments is investigated in detail in Chapter 5, and, without pre-empting the results presented in that Chapter too much, it is clear that the majority of assortment boxes have faults (holes or gaps) in the overwrapping at the time of manufacture. Such packaging imperfections not only provide entry points for insect pests (Mullen and Highland, 1988), but they also allow the release of odours that are attractive to insect pests (see Chapter 5). The PVC film used to overwrap the majority of assortment boxes can also be penetrated by several stored product insect species (see Chapter 5). Therefore, a combination of inadequate packaging and extended storage periods is thought to be the primary reason why assortment products are most often infested.

Given this, it is possible that improvements in both of these areas contributed to the declining trend in the assortment complaint rate, and consequently the overall complaint rate, from 1990 to 1994. While it is unlikely that the storage periods of assortments were significantly reduced during this period, the company's sales staff generally encourage retailers to continually rotate stock to minimise storage periods, so possibly some improvements were made.

A factor more likely to have led to the decline in complaints, however, was an alteration to the technique used to package assortments. Prior to 1992, every assortment box was overwrapped with a PVC shrink-wrap film that was perforated with 3 holes (~3mm diameter) to aid the shrinking process and achieve a neater finish. However, at the end of 1991, a machinery change-over resulted in the overwrap subsequently being applied to assortment products without intentional perforations (B. Brassington *pers. comm.*). Therefore, from 1992 onwards, the integrity of assortment packaging was no doubt improved, leading to a significantly reduction in the risk of insect invasion (Mullen and Highland, 1988; Yerington, 1978). While a high proportion of assortment products still have an unintentional packaging defect of some description at the time of manufacture (see Chapter 5), the improvement to the overall package integrity by eliminating intentional perforations was probably an important factor in the reduction in product infestation post-1991.

Another factor that was probably significant in the reduction of assortment complaints was the decline in production of many evidently susceptible assortment lines, and consequently, their decreased apparency in the marketplace. This is probably a fortunate consequence of the management policy to contract the product range base and concentrate on the production Roses and Milk Tray lines, which had consistently lower rates of infestation than products (e.g. Milk Dark Selection, Rich Dark Selection, Fine Milk Selection, Dark Favourites, Milk Favourites) whose production either decreased markedly from 1990 to 1994, or were phased out altogether. The increase in, particularly, Roses production, offset the decrease in production of these other lines, which helped mask the effect that the decreasing product range base had on infestation complaint trends.

It is unlikely that that fluctuations in insect pest apparency throughout the distribution and retail networks were responsible for the decline in assortment complaints. It is unlikely that insect pest populations would have varied in such a uniform manner as to result in an assortment complaint rate trend that was consistent between all Australian states from year to year. Factors common to all states, such as the contraction of the product range and improvements to package integrity, were more likely to be responsible for the declining trend.

The overall decline in product infestation should not be allowed to lead to a sense of complacency when dealing with the infestation problem. The highest selling assortment product, 250g Roses, has recorded an increased rate of infestation over the period 1990 to 1994, as has another important assortment product, 250g Hazelnut Whirls. If such trends were to continue, the infestation rate may again reach pre-1992 levels within a short period of time.

The discussion examining trends in assortment/overall infestation complaints has, up to this point, concentrated upon factors influencing post-packaging infestation, that is, the invasion of goods after they have been packaged at Claremont and shipped interstate (no finished product is stored at Claremont). It has not dealt with the possibility of pre-packaging infestation, that is, insect contamination at the factory prior to packaging, and how this might influence complaint trends. This is because investigations into the origins of infestation (presented in Chapter 3) indicate that most infestation occurs post-packaging. The finding that the complaint rates of non-assortment products remained virtually unchanged over the sample period (1990-1994) suggests that post-packaging infestation also predominated during this period. If fluctuating insect pest populations at the factory led to the fluctuations in the assortments complaint trend, then the complaint trends for non-assortment products would have been expected to vary in a similar fashion, being exposed to the same insect population dynamics. As this was not the case, and given the results presented in Chapter 3, it is therefore believed that the assortment/overall complaint trend was primarily dependent upon the rate of occurrence of post-packaging infestation, rather than pre-packaging infestation.

The finding that the rate of occurrence of infestation was dependent upon geographic/temperature factors was similar to that reported by Highland (1984) who observed that, in the United States, the incidence of package infestations increases as one moves south due to the longer, warmer, more humid summers providing longer favourable growth periods for insects. In the Australian context, extended periods of warm, humid conditions in the more northerly regions no doubt provide similar favourable conditions for insect growth and development. Consequently, produce stored in these areas are probably exposed to greater numbers of insects for longer periods than produce stored in southern regions. The reason for the generally higher rate if infestation in WA is not completely understood, although the warm climate is obviously a factor. The possible prevalence of the Indianmeal moth, *Plodia interpunctella* (Hübner), in West Australian storage facilities (see Chapter 3), and the apparently superior ability of this species to penetrate packaging materials (see Chapter 5), may provide an answer.

Produce manufactured in spring is probably at greater risk of becoming infested because it is likely to be stored during the following summer, when insect pests are likely to be most abundant. This is consistent with the observations of Highland (1984) and Anon. (1969) that infestation of packaged goods increases as summer progresses. Sales are also slightly lower during the warmer months of the year (R. Berry *pers. comm.*) which possibly results in a slower turn-over of stock than during cooler months. Consequently, stock manufactured in spring is probably exposed to a greater number of insect pests for longer periods than stock manufactured at other times of the year, and is therefore more likely to be infested.

The finding that products containing nut ingredients generally have a higher rate of infestation than products without nuts, agrees with the observations of Highland (1984) that some foods more likely to become infested than others. This result is perhaps not surprising given the findings of Johnson *et al.* (1995). They examined the performance of *P. interpunctella*, the species most commonly associated with infested Claremont produce (see Chapter 3), on diets of wheat bran, nuts (almonds, pistachios and walnuts) and dried fruit (raisins and prunes). They found that although the wheat bran was the most favourable diet for *P. interpunctella*, in terms of survival, development and fecundity, the nut varieties were only marginally inferior, while the dried fruit varieties led to significant mortality and delayed development. This probably explains why chocolate-based products containing nut are more likely to be infested than those containing solely dried fruit ingredients. Preliminary performance trails undertaken by the author (data not presented) have shown that both *P. interpunctella* and the almond moth, *Ephestia cautella* (Walker), also experience high mortality and delayed development when confined to a diet consisting solely of milk chocolate, which probably explains why products consisting of only chocolate are also rarely infested.

A higher than expected proportion of infestation produce was purchased from the 'traditional' retail sector than from the 'grocery' sector. Assuming that a significant proportion of infestation actually occurs at the retail level of distribution (which is thought to be a valid assumption; see Chapter 3), this finding may be due to a number of factors. Firstly, stock turn-over rate might again be important; the smaller outlets that comprise the traditional retail sector, generally have a slower rate of product turn-over than the large supermarkets that comprise the grocery sector (R. Berry *pers. comm.*). Secondly, this result might reflect a greater occurrence of stored-product insects within the traditional sector. Thirdly, the practice of displaying products (particularly assortments) on high shelving close to the ceiling in smaller outlets may also increase the likelihood of infestation; insect activity is likely to be greatest in these warmer, upper regions (Graham, 1970), and attractive odours escaping from products might also become concentrated in the confined headspace, thereby alerting insect pests to the presence of a potential food source (see Chapter 5).

The remarkably consistent rate of infestation of product other than assortments might suggest that products were infested in the same stores recurrently. Certainly, a preliminary inspection of the database revealed that the same stores were often repeatedly implicated in infestation complaints (Appendix II). At present, however, this is merely speculation, and a more comprehensive analysis of the database containing outlet details, and follow-up investigation of individual outlets would be required to establish the validity of this hypothesis.

Even though the incidence of infestation was relatively low, the economic costs associated with infestation complaints were considerable. It was estimated that infestation cost the company almost $½m during the years 1990 to 1994. Most of these costs were due to losses associated with the infestation of assortment products.

This was due to the generally higher retail value of assortments compared to other products. It must be remembered that the costs quantified in this Chapter represent only the 'avoidable' costs, that is, those costs directly attributable to a quality fault (Juran and Gryna, 1970). The avoidable costs represent the amount that can be justifiably outlaid in order to reduce the incidence of a quality fault (Juran and Gryna, 1970). Expenditure of approximately $100,000 p.a. to reduce the incidence of infestation, particularly in assortment products, could therefore be economically justified. Of course, it must be remembered that infestation is primarily a quality issue and, although economic considerations need to be taken into account, a solution that requires expenditure of more than $100,000 p.a. could be justified on the grounds of ensuring a high quality product.

In conclusion, analysis of the consumer complaint databases has confirmed a number of observations concerning insect infestation of packaged goods previously reported, and provided a useful insight into some additional factors that influence the infestation of goods manufactured at Claremont. The results allow a risk profile of stock to be formulated. A product is most likely to be the subject of an infestation complaint if it:

- is manufactured in spring,
- contains a nut ingredient,
- lacks complete package integrity,
- is stored for an extended period,
- is sold from a traditional retail outlet,
- is purchased in northern Australia.

Of course, not every item that fits this profile will inevitably become infested. The essential requirement for infestation is exposure to insect pests, which due to the very low overall infestation rate, is probably extremely rare. However, these findings clearly indicate that the key to further reducing the number of infestation complaints lies with minimising the convergence of the above factors. Obviously, any attempt to limit the sale of stock from traditional retail outlets in northern Australia would be counter-productive, as would eliminating nut ingredients from produce, and minimising the amount of product manufactured in spring may be impractical. However, implementing initiatives to minimise the incidence of packaging imperfections and slow product turn-over rates, are realistic proposals that could further reduce the incidence of product infestation. These proposals are discussed in detail in Chapter 6 where specific recommendations, concerning strategies aimed at minimizing product infestation, are also presented.

CHAPTER 3

Identification of insect agents and estimation of the origins of infestation

3.1 INTRODUCTION

Insect pests can potentially invade most packaged goods at any time from manufacture to consumption; goods can become infested during production, shipment, or storage at wholesale and retail level (Highland, 1984). With regard to confectionery produce, generally only a very small proportion of products become infested at factories, with the majority infested during distribution (Anon., 1969).

The distribution route taken by goods produced at the Claremont factory is often complex. The flow-chart shown in Fig. 1 illustrates the distribution network prior to 1995. It shows the levels that goods, within the network, moved through, and how the components of the network interacted. It also shows the number (in parentheses) of wholesalers and retailers that handle Cadbury Schweppes goods.

All produce manufactured at Claremont was shipped to the main distribution centre in Ringwood, Victoria. From there, it was either transported to interstate Cadbury Schweppes distribution centres, sold to independent wholesalers, or sold directly to corporate supermarket chains. Reselling sometimes took place between the supermarket chains and the wholesalers, and the Cadbury Schweppes distribution centres in each state also supplied the corporate supermarket chains and wholesalers. Independent retailers then bought stock from either Cadbury Schweppes or the wholesalers before the product finally reached the customer, while the supermarket chains sold goods directly through their stores. At the end of 1994, all of the Cadbury Schweppes distribution centres were sold so that, at the time of writing, all distribution was controlled by operators independent of Cadbury Schweppes.

To determine at what stage of this process produce is most likely to become infested, it was decided to, firstly, survey infested goods returned by customers to determine the insect agents responsible and, secondly, to identify where those insects occurred along the distribution network so that the origins of infestation could be estimated.

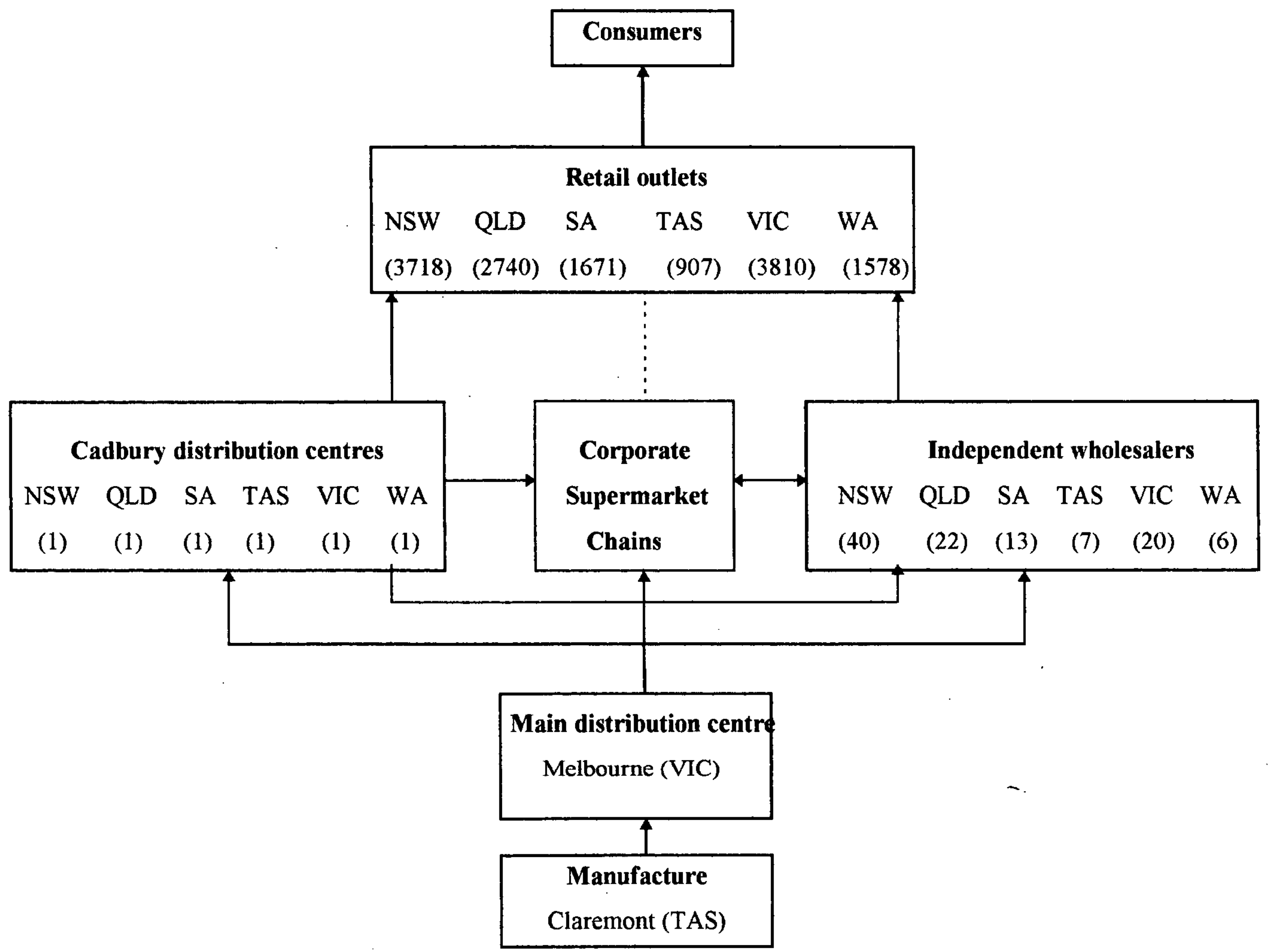


Fig. 1. Product distribution network. The numbers in parentheses indicate the number of wholesalers or retailers that handle stock.

3.2 MATERIALS AND METHODS

3.2.1 Inspection of returned infested goods

Infested produce returned to the Claremont factory between January 1994 and May 1995 was inspected for insect pests. Only ~20% of consumer complaints are processed at Claremont, the remainder are processed at the Ringwood plant in Victoria. Not all of the infestation-related consumer complaints directed to Claremont could be inspected by the author because the actual product was sometimes not returned by the customer. Also, samples were sometimes discarded before they could be inspected.

Insects were identified according to the keys contained in the British Museum (Natural History) (1980) guide to common insects of stored food products. Following inspection, company records were examined to ascertain the customer details of each complaint, and the retail outlet from which products were purchased. Unfortunately, inspected goods could not always be matched with company records, and retail outlet details were only sporadically recorded. All data concerning returned infested goods is presented in Appendix V.

Retail outlet details were used to plot the geographic origin of complaints. When these details were not available, the address of the complainant was used. In such cases, it was assumed that consumers purchased goods from outlets close to their homes.

3.2.2 Survey of stored-product insect occurrence throughout the manufacture and distribution network

Due to the enormous number of wholesalers and retailers that handle stock manufactured at Claremont, a comprehensive survey of all components of the distribution network was beyond the scope of this study. Therefore, insect surveys were restricted to the Claremont factory, the main distribution centre in Melbourne and the Cadbury Schweppes-controlled distribution centres in each state. Unfortunately, the Cadbury Schweppes distribution centres in New South Wales, Queensland, Victoria (a separate facility from the main distribution centre) and

Tasmania (a separate facility from the Claremont plant) were sold before they could be sampled.

The materials and methods used to sample storage moths at the Claremont factory are presented in Chapter 4. Other stored-product pests present at the factory were identified but no attempt was made to quantify their populations.

In each of the other facilities, 12 pheromone (International Pheromone Systems Ltd., UK) baited sticky traps (Pherocon II, Trécé Inc., Salinas CA) were deployed for 8 weeks to sample storage moth populations. These facilities were sampled during the warmer months to maximise the likelihood of capturing storage moths, and no attempt was made to survey other insect pests that might have been present.

The main distribution centre, located in the Melbourne suburb of Ringwood was sampled from February to April 1995, and comprised a single automated pallet storage facility (~90 x 90 x 30m). Three traps (~20m apart) were placed along each of 4 horizontal maintenance walkways that ran through the centre of the storage area. The walkways ran directly above each other at an incremental height increase of ~5m, with the lowest walkway ~5m from the floor. Temperature was automatically controlled (17-21°C), sanitary conditions were good, and no insect pest control measures were implemented during the sampling period.

The West Australian distribution facility, located in the Perth suburb of Welshpool, was sampled from October to December 1994. The warehouse comprised a single facility of 4 interconnecting storage rooms (Appendix VI). Three traps were placed in each room, and position of each trap (indicated by a circle) is shown in Appendix VI. All traps were hung from storage racks at a height of ~2-3m. According to personnel, synergised pyrethrins had been applied to the warehouse each fortnight for the previous 15 years, either by hand-spraying or via a 'fixed' system that delivered the pesticide through ceiling jets, and there had been no recent history of storage moth activity. Synergised pyrethrins were applied to the warehouse during the sampling period. Temperature was manually controlled (coolers turned on when conditions were deemed to be too warm) and had varied from 11-24°C over an unknown period of time when the room thermometers were inspected by the author.

The warehouse was filled to ~60-70% of capacity when the traps were initially deployed.

The South Australian distribution facility, located in the Adelaide suburb of Hindmarsh, was sampled from September to November 1994. The warehouse comprised 2 interconnecting storage areas (Appendix VI). In the smaller room, three traps were placed along the walls at a height of ~3m. The remaining 9 traps were dispersed throughout the larger room, again at a height of ~3m. These traps were either hung from walls or attached to storage racks. The position of traps (indicated by circles) in each room is illustrated in Appendix VI. Synergised pyrethrins had been applied to the warehouse each fortnight for approximately 19 years (B. Rowe *pers. comm.*). The pesticide was delivered via ceiling jets, and there had been no recent history of storage moth activity (B. Rowe *pers. comm.*). Synergised pyrethrins were applied to the warehouse during the sampling period, temperature was automatically controlled (17-21°C), and the warehouse was filled to ~30-40% of capacity when the traps were initially deployed.

Insects were identified according to the keys contained in the British Museum (Natural History) (1980) guide to common insect pests of stored food products, although identification of all individuals collected in sticky traps was not possible due to fouling by the adhesive.

3.3 RESULTS

3.3.1 Inspection of returned infested goods

A total of 141 infested products, returned to the company by consumers, were inspected. These complaints represented ~11% of the total number of infestation complaints lodged during this period. Both the distribution of complaints between product groups, and the 'age' of returned goods were similar to that found in Chapter 2; assortment products were most often infested, and the goods were, on average, approximately 9 months old (Table 1). The 'Roses', 'Milk Tray' and 'Hazelnut Whirls' assortment products were most often returned by customers (Appendix V).

Table 1. Product group category and 'age' of returned infested goods inspected by the author between January 1994 and May 1995.

Product group	Complaints	Age	
		$\overline{x}$ (days)	SD (days)
Assortments	101	272.10	81.90
Moulded	36	245.30	81.89
Bars	3	-	-
Children's	1	-	-
Total	141	266.31	82.32

The distribution of infestation complaints between states was also similar to that found in Chapter 2 with most complaints originating from the warmer, northerly states (NSW, QLD and WA), and fewer from the southern states (Fig. 2).

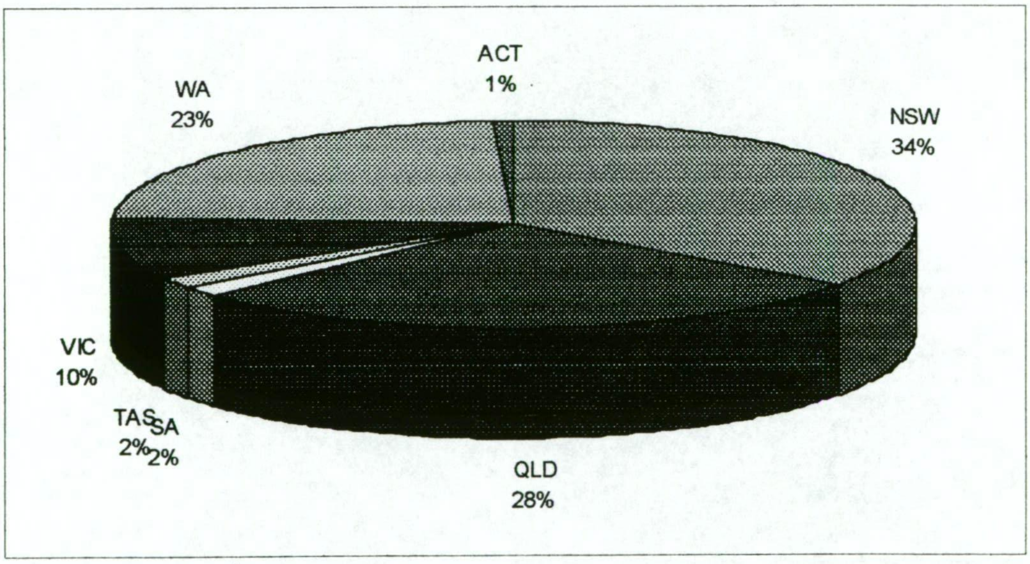


Fig. 2. Proportion of returned infestation complaints originating from each state or territory inspected by the author between January 1994 and May 1995. The abbreviations refer to the Australian Capital Territory (ACT), New South Wales (NSW), Queensland (QLD), South Australia (SA), Victoria (VIC), Western Australia (WA) and Tasmania (TAS).

Lepidoptera were responsible for the infestation of almost all of the goods inspected (Appendix V). This was determined by the presence of live or deceased larvae or adults, body fragments, chrysalis', or the presence of characteristic frass and webbing on the product (see Fig. 4 of Chapter 1). Fifty returned products contained insect pests that were able to be identified. As shown in Table 2, all pests recovered were phycitine moths, except for one case where the coleopteran *Oryzaephilus surinamensis* was found. The Indianmeal moth, *Plodia interpunctella*, and various species of *Ephestia* were most commonly associated with infested stock. Generally fewer than 5 larvae were found on infested goods, although on heavily infested goods, many more larvae and adults (usually deceased) were collected. The greatest number of larvae and adults recovered from one item was 48.

Table 2. Insect species recovered from infested product.

Order	Family	Subfamily	Species	Common name	Occurrence on produce (%)
Lepidoptera	Pyralidae	Phycitinae	*Ephestia cautella*†	Almond moth	13 (26)
		Phycitinae	*Ephestia elutella* (Hübner)	Tobacco moth	5 (10)
		Phycitinae	*Ephestia figulilella* (Gregson)†	Raisin moth	1 (2)
		Phycitinae	*Ephestia kuehniella* (Zeller)	Mediterranean flour moth	2 (4)
		Phycitinae	*Paralipsa gularis* (Zeller)	Stored nut moth	2 (4)
		Phycitinae	*Plodia interpunctella*	Indianmeal moth	26 (52)
Coleoptera	Silvanidae	-	*Oryzaephilus surinamensis* (L.)	Sawtoothed grain beetle	1 (2)
Total					50 (100)

† These species are sometimes placed in the genus *Cadra* (Walker), and, while there is some justification for this, their appropriate classification has not yet been determined conclusively (Horak, 1994). Both species are assigned to the genus *Ephestia* throughout this thesis.

While the sample size was too small to clearly indicate particular product preferences of *P. interpunctella* and *Ephestia* spp., it is clear that both infest a wide variety of produce (Table 3). Of these, all, with the exception of 200g Liqueur Cherries, 250g Caramello and 5*15g Dairy Milk, had a variety of nut either as a constituent of a moulded block, or as an ingredient of units contained within assortments boxes. Indeed, nuts were a integral ingredient of most (87%) infested products inspected by the author (Appendix V), and most feeding damage was associated the nuts, rather than the chocolate or other ingredients.

Table 3. Products infested by *Plodia interpunctella* and *Ephestia* spp.

Product group	Product	*Ephestia* spp.	*P. interpunctella*
Assortments	200g Liqueur Cherries	0	1
	200g Roses	0	1
	250g Hazelnut Whirls	0	6
	250g Milk Favourites	1	0
	250g Milk Tray	3	0
	250g Roses	7	3
	300g Milk Tray	0	1
	300g Roses	0	1
	500g Milk Tray	3	3
	500g Roses	2	2
Moulded	250g Brazil Nut Milk	0	1
	250g Caramello	1	1
	250g Cashew Nut Milk	2	0
	250g Fruit and Nut Milk	0	1
	250g Hazelnut Milk	1	0
	250g Roast Almond	0	1
	275g Fruit and Nut Milk	0	1
	55g Fruit and Nut Milk	0	1
	55g Hazelnut Milk	0	1
	55g Roast Almond	1	0
Children's	5*15g Dairy Milk	0	1
Total		21	26

While, again, the sample size was too small to draw clear conclusions, the distribution of *Ephestia* spp. and *P. interpunctella* between states appears to differ. While both *Ephestia* spp. and *P. interpunctella* were collected from goods returned from New South Wales, Queensland and Victoria, only *P. interpunctella* was collected from complaints that originated from Western Australia (Table 4).

Table 4. Distribution of complaints involving *Ephestia* spp. and *Plodia interpunctella* between states. NSW - New South Wales, QLD - Queensland, VIC - Victoria, WA - Western Australia.

State	*Ephestia* spp.	*P. interpunctella*
NSW	9	8
QLD	6	5
VIC	5	2
WA	0	10
Total	20	25

Goods infested by *Ephestia* spp. and *P. interpunctella* were purchased mainly in state capital cities, although a number were also purchased in regional centres (Fig. 2).

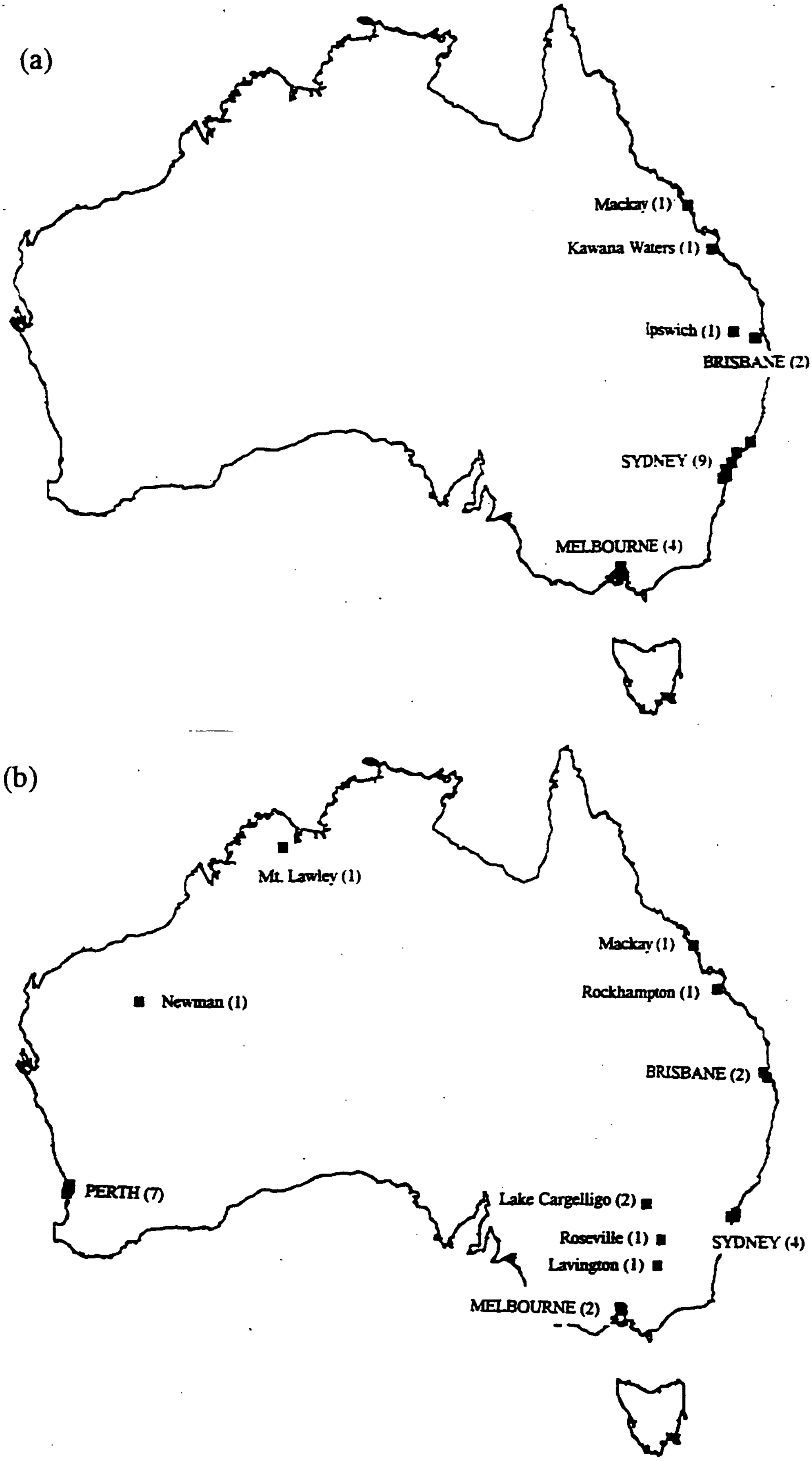


Fig. 3. Place of purchase of products infested with (a) *Ephestia* spp. and (b) *Plodia interpunctella*. The number of infested products purchased in each state capital city (uppercase) or regional centre (lowercase) is shown in parentheses.

3.3.2 Survey of stored-product insect occurrence throughout the manufacture and distribution network

Results from the insect pest surveys conducted at points along the distribution networks revealed that only lepidopteran species of the genus *Ephestia* were captured (Table 5). The species *Ephestia cautella* was captured in all facilities, although only in low numbers in the distribution warehouses. Many *E. cautella* were captured at the Claremont factory over the 12 months sampling period. Two coleopteran species, the sawtoothed grain beetle *Oryzaephilus surinamensis* and the confused flour beetle *Tribolium confusum*, were also found at the factory, as was the German cockroach, *Blattella germanica*.

Table 5. Stored product insect pests collected at Cadbury Schweppes manufacturing and distribution facilities. n - number of individuals captured.

Facility	~Volume ($\times 100m^3$)	No. traps	Sampling period	Species collected	n
Claremont production plant, Hobart, TAS.	920	158*	March 1994 - March 1995	*Ephestia cautella* *Oryzaephilus surinamensis* *Tribolium confusum* (Jacquelin du Val) *Blattella germanica* (L.)	1139 - - -
Ringwood distribution centre, Melbourne, VIC.	2430	12	February - April 1995	*Ephestia cautella* *Ephestia elutella*	8‡
Welshpool distribution warehouse, Perth, WA	133	12	October - December 1994	*Ephestia cautella*	7
Hindmarsh distribution warehouse, Adelaide, SA.	78	12	September - November 1994	*Ephestia cautella* *Ephestia kuhniella*	6‡

* - No. of moth traps initially deployed.

‡ - Total no. of moths captured.

3.4 DISCUSSION

Phycitine moths, particularly species of the *Ephestia* genus and *Plodia interpunctella*, are major pests of stored products throughout the world (Hill, 1990). The pest status, distribution and life history of phycitine pests of stored products is adequately covered by Hill (1990), and can be summarised as follows. While phycitines are mostly tropical in distribution, they are also found in heated stores in temperate regions. They are multivoltine insects, and females may lay 300-500 eggs during their lifetimes. Optimal conditions for development are at about 30°C and 70% relative humidity, at which development from egg, through (usually) 5 larval instars, to adult is completed in approximately 22-28 days. Many species enter diapause during the final larval instar if suboptimal conditions (eg. low temperature, short photoperiod, overcrowding) are experienced. Phycitines can feed on all types of produce of plant origin including dried fruits, nuts, seeds, grains, cocoa beans, tobacco, flour, meals, dates, chocolate, dried roots and herbs (Hill, 1990).

While the degree of sampling along the distribution networks was insufficient to conclusively determine the origins of infestation, it is clear that most infestation occurs post-packaging, that is, once stock has left the Claremont factory. This agrees with the observations of Anon. (1969). Of the stored-product insects identified from infested produce, only *Ephestia cautella* and *Oryzaephilus surinamensis* were also found at Claremont, and these species accounted for only 28% of returned infested goods. Probably not all product infestation attributable to *E. cautella* had its origins at the factory either. This species most likely occurs sporadically throughout the distribution and retail networks. Indeed, it was found in the 3 interstate distribution warehouses that were sampled. Therefore, *E. cautella* infestation probably also occurs post-packaging as well as at the factory. Consequently, the actual proportion of complaints that originate from Claremont is likely to be less than 28%.

The species that most often infested goods, the Indianmeal moth *Plodia interpunctella*, was not captured at any of the facilities that were sampled, and only very few *Ephestia* spp. individuals were captured in the distribution warehouses. Assuming that the other Cadbury Schweppes distribution warehouses not sampled in this study were also free of major infestations, which anecdotal evidence suggests (R. Berry *pers. comm.*), the majority of infestation must occur while stock is either in the possession of independent wholesalers, retailers or customers, or while stock is being transported.

The proportion of infestation complaints attributable to each of these components of the distribution network cannot be determined conclusively without further sampling. However, based on the assumed degree of protection provided to produce by packaging materials as it moves through the distribution network, likely points of origin can be estimated. Once individual products are wrapped at Claremont, a certain number are placed into sealed cardboard boxes (or 'outers' as they are called in the industry). The outers are then placed into larger cardboard containers which are sealed for transportation. While cardboard boxes are not completely insect proof (Highland, 1984), the more packaging that is applied, the greater the difficulty insects experience attempting to gain entry (Anon., 1969). Therefore, as long as stock is encased within these cardboard containers (generally throughout transportation and storage) they will remain reasonable well protected from insect attack provided the boxes are not opened or ruptured. Goods are usually only removed from the cardboard containers once they are to be displayed in retail outlets. It is at this time, when produce lacks the additional protection afforded by the cardboard boxes, that produce is probably most vulnerable to phycitine attack, and possibly when most infestation occurs. However, it must be repeated, that without further investigation, this hypothesis cannot be verified.

Phycitines are common pests of packaged goods, and are categorised as 'penetrators' (Highland, 1984) because their ability to bore through a wide variety of packaging materials. It was clear from inspecting returned infested goods that phycitines can readily penetrate the materials used to package moulded and bar products. It has also been found that *P. interpunctella* and *E. cautella* can penetrate materials used to package assortment products (see Chapter 5). Therefore, the poor insect barrier properties of materials used to package Claremont produce is one reason for the high rate of post-packaging invasion of goods by phycitines. A detailed examination of the factors and behaviour that influence the post-packaging infestation of assortments by two phycitines, *P. interpunctella* and *E. cautella*, is presented in Chapter 5.

The presence of *E. cautella* at each of the distribution warehouses that were sampled suggests that individuals from the population at Claremont are radiating through the distribution and retail networks via packaged goods. This has serious consequences as emergent adults can potentially establish colonies in warehouses and retail outlets that handle Cadbury Schweppes products, and subsequently infest previously uncontaminated, incoming goods. The small number of *E. cautella* captured in the distribution warehouses suggests that, at the time of sampling, populations had not become established, but the potential remains as long as *E. cautella* persists at Claremont.

The finding that only *P. interpunctella* was collected from infested goods returned from West Australia was interesting, particularly since *P. interpunctella* and *Ephestia spp.* are found in approximately equal proportion in grain storage facilities within the state (R. Emery *pers. comm.*). There are three possible interpretations of this result. Firstly, the finding may merely be a function of the small sample size. Secondly, it is possible that *P. interpunctella* is the predominant species infesting Western Australian retail outlets. Thirdly, product is being infested at a wholesale holding facility before being distributed to retail outlets. This final possibility is perhaps the most likely. The majority of cases were reported from inner-Perth suburbs, and if retail outlets in these areas were supplied by the same wholesaler(s), then it is reasonable to assume that infestation cases from those outlets might have their origins with the wholesaler(s). Also, if stock was being infested at one, or a number of wholesale holding facilities, it might explain why Western Australia has the highest rate of infestation in the country (see Chapter 2). Further investigations are required to fully understand the infestation of stock by *P. interpunctella* in Western Australia.

It was apparent that nuts were the preferred food source for phycitine larvae infesting goods manufactured at Claremont. In most infested assortment boxes, for example, a particular unit, the 'hazelnut whirl', was often the only unit consumed by larvae. This unit consists of a whole, shelled, roasted hazelnut placed on a bed of milk chocolate and covered by a swirl of milk chocolate. All 'Roses' and 'Milk Tray' boxes contain hazelnut whirl units, and 'Hazelnut Whirl' boxes contain exclusively hazelnut whirl units. The nut inside the hazelnut whirl unit was clearly the preferred food source of phycitine larvae, with the chocolate encasing the unit only occasionally consumed (Fig. 4; see also Fig. 4 of Chapter 1). The milk or dark chocolate coatings that encased other units was also only occasionally eaten and the centres of other assortment units were rarely consumed. Even the units that contained a processed nut centre (eg. nut caramel) were rarely eaten. The units with soft centres were

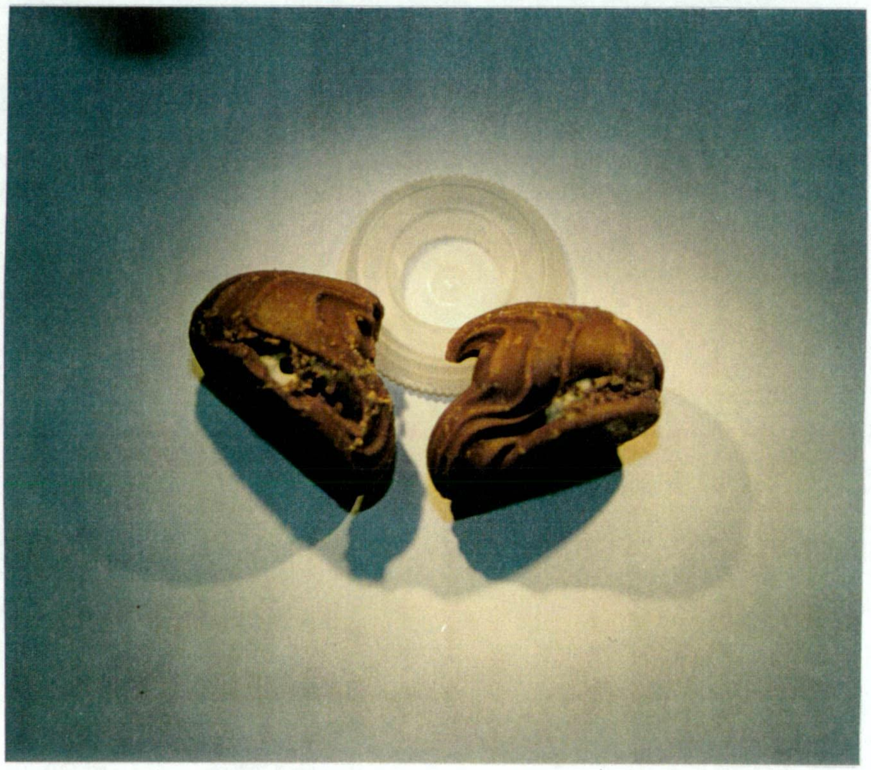


Fig. 4. 'Hazelnut whirl' assortment units with severe damage to whole hazelnuts inflicted by phycitine larvae (x0.8).

particularly avoided, perhaps because of the likelihood of larvae being trapped by the filling, but possibly also because the centres were a nutritionally poor food source. In moulded blocks too, nuts were the most likely feature of the unit to be eaten by larvae (see Fig. 4 of Chapter 1). Again, chocolate was sometimes consumed, but often in order to gain access to nut fragments that were interspersed throughout a block. Dried fruit components of moulded blocks were occasionally eaten although not in preference to nuts. These observations supported the apparent food preferences of insect pests inferred in the data presented in Appendix I and discussed in Chapter 2.

It was often found that hazelnut whirl units which were not fully encased by chocolate were severely damaged, while other hazelnut whirl units in the same box that were completely encased, remained undamaged. This implied that covering the nut made the unit less attractive to invading phycitines. The reasons for this were probably twofold; by completely encasing the hazelnut, larvae could not gain direct access to the nut and; attractive odours emitted by the nut were probably reduced or masked (phycitine larval orientation and movement in response to hazelnut odours is examined in Chapter 5). Consequently, by completely encasing the hazelnut, the preferred food source was essentially 'hidden' from invading larvae, and possibly also from gravid females searching for oviposition cues externally.

A number of other observations of interest were made while inspecting returned goods. Firstly, more than one phycitine generation was found infesting assortment boxes on a number of occasions. Secretions deposited by conspecific larvae within the boxes probably made already infested products more attractive to gravid females as oviposition sites than uninfested products (Andrews and Barnes, 1982; Corbet, 1973; Phillips and Strand, 1994).

Secondly, phycitines were able to complete development within assortments boxes, with deceased adults sometimes recovered. The presence of abundant frass and webbing, and larval head capsules ranging in size from small to large, suggested that individuals had not entered packages at a late stage of development, but developed fully by exclusively consuming produce. The ability of phycitines to complete development within assortment boxes was confirmed in experiments described in Chapter 5. These experiments also found that adults were able to mate, and the females oviposit, within boxes, although no such evidence (e.g. egg casings) was found in the returned complaints. The presence of conspecific adults in assortment boxes may have also made already infested products more attractive to gravid females as oviposition sites, than uninfested products (Barrer, 1977).

Thirdly, phycitine larvae occasionally left packages during the latter stages of development. This was concluded after finding a great deal of damage to a product, but no larvae, adults, chrysalis' or body fragments. Late instar larvae are very active and sometimes leave produce while searching for a suitable site to pupate (Hill, 1990). The *E. cautella* adults captured in the distribution warehouses may have pupated and emerged in the stores after developing in, and later leaving, packages which were initially infested at Claremont.

Fourthly, while larvae sometimes left packages to pupate, many stayed within assortment boxes and pupated in the laminated paper inserts that are used to pad the boxes. The corrugations in the padding were ideal for the construction of the simple galleries in which larvae pupated. Larvae also pupated on the twist-wrappers that are sometimes used to wrap individual assortment units within boxes. The depressions in moulded products also provided suitable sites for pupating larvae. Generally, any type of crevice that a larva could wedge itself into appeared to be suitable as a pupation site.

Fifthly, on one occasion a late instar larva was found on an undamaged moulded product. It was possible that the larvae had penetrated the product packaging during its search for a suitable pupation site. Consequently, not all larvae found within products may have invaded in search of a food source, although this was generally the case.

In conclusion, it is clear that phycitine moths are responsible for almost all cases of infestation. Infestation generally occurs post-packaging, possibly while stock is on display in retail outlets, although some infestation no doubt also occurs during storage, transportation, or in consumer households. Nuts are the key ingredient attracting phycitines, while the packaging and shape of products provides ideal crevices for pupating larvae. Also, *E. cautella* may be radiating from the factory through the distribution network and, consequently, posing a threat to incoming, uninfested goods. While a detailed discussion of the strategies needed to reduce the incidence of infestation are presented in Chapter 6, it is clear that, from the results presented in this Chapter, retailers and wholesalers need to be educated about the risks that phycitines pose to stored goods, and made aware of methods of identification and eradication, so that product exposure to phycitines is minimized. Also, the nuts contained in the 'hazelnut whirl' assortment unit need to be completely encased by chocolate, and the use of packaging materials resistant to penetration by phycitine larvae needs to be investigated. Every attempt also needs to be made to eradicate *E. cautella* from Claremont.

CHAPTER 4

Evaluation of current and alternative strategies to control *Ephestia cautella* (Walker) (Lepidoptera: Pyralidae) at the Claremont production facility

4.1 INTRODUCTION

The almond moth, *Ephestia cautella* (Walker), is a major pest of stored products throughout the warmer parts of the world, and in heated stores in temperate regions (Hill, 1990). At the Cadbury Schweppes' Claremont confectionery factory, *E. cautella* is believed to be responsible for the infestation of a small proportion of finished product. *E. cautella* is managed by regularly fogging the factory with synergised pyrethrins. However, due to public health concerns regarding the use of pesticides, an alternative strategy to manage *E. cautella* was sought.

Environments such as that found within the factory, lend themselves favourably to insect management by pheromones (Burkholder and Ma, 1985). Pheromone traps have previously been successfully employed to detect and monitor storage moths in food storage and processing environments (e.g. Hoppe and Levinson, 1979; Levinson and Buchelos, 1981; Mullen *et al.*, 1991; Šifner *et al.*, 1983; Vick *et al.*, 1986). Reported here are the results of an extensive trapping program undertaken at the factory to determine the viability of managing *E. cautella* by pheromones. The results include findings on the spatial and temporal distribution of *E. cautella* within the factory, the causal factors determining *E. cautella* distribution and, an evaluation of *E. cautella* control achieved through the regular, blanket application of synergised pyrethrins.

During the study it became apparent that *E. cautella* was particularly abundant in one room. Therefore, a separate study was devised to determine whether the mass trapping technique could be used to suppress this population.

Ever since the identification of attractive sex pheromone components by Brady *et al.* (1971) and Kuwahara *et al.* (1971), numerous attempts to control phycitine populations through pheromonal manipulation have been made. Studies have shown that high background levels of the attractive component of the pheromone complex, (Z,E)-9, 12-tetradecadienyl acetate, can disrupt mating behaviour and suppress population growth (Brady and Daley, 1975; Haines and Read, 1977; Hodges *et al.*, 1984; Sower and Whitmer, 1977; Süss and Trematerra, 1986). The mass trapping technique, where many pheromone baited traps are introduced into infested environments to 'trap-out' males, has also been found to effectively suppress phycitine populations (Pierce, 1994; Šifner *et al.*, 1983; Süss and Trematerra, 1986; Trematerra and Bataini, 1987), although the degree of control attributable to the removal of males from a population is generally not able to be differentiated from that attributable to other possible suppressants such as mating disruption or the clean-up of local infestations. Reported here are the results of 45 weeks of mass trapping *E. cautella* within a room of the confectionery factory.

4.2 MATERIALS AND METHODS

4.2.1 Pheromone monitoring study

The study was conducted from March 1994 to March 1995. Floor plans of the factory, the position of each trap and the number of moths captured in each trap during the study are shown in Appendix VII [the number of moths captured in room 'Z' represents only those captured from March 1994 to May 1994 (see below)].

Commercially available sticky traps (Pherocon II, Trécé Inc., Salinas CA) and pheromone lures (International Pheromone Systems Ltd. (IPS), UK) were used (Fig. 1). Details concerning the loading and release rate of the pheromone lures were not supplied by the manufacturer. The active compound in the pheromone lures was the adult male attractant (Z,E)-9,12-tetradecadienyl acetate.

All pheromone trapping took place inside the factory. Initially, 153 traps were deployed with the pheromone lures replaced every 8-10 weeks and traps renewed when they became ineffective due to moth or dust accumulation. Traps were placed 10-15m apart, at a height of approximately 4m above the floor, and a minimum distance of 0.5m from walls. They were generally hung from overhead piping and were placed in a grid formation where possible. Traps were lifted onto and off piping using a 2m wooden pole with a U-shaped hook attached at one end (Fig. 2). The number of traps and position of each remained constant in all rooms except two (see below).

Traps were placed throughout four floor levels and covered most (~90%) storage, processing and finishing areas. The 35 rooms sampled ranged in size from 25m^2 to 2800m^2, with a total of ~23000m^2 of floor space covered. All rooms were

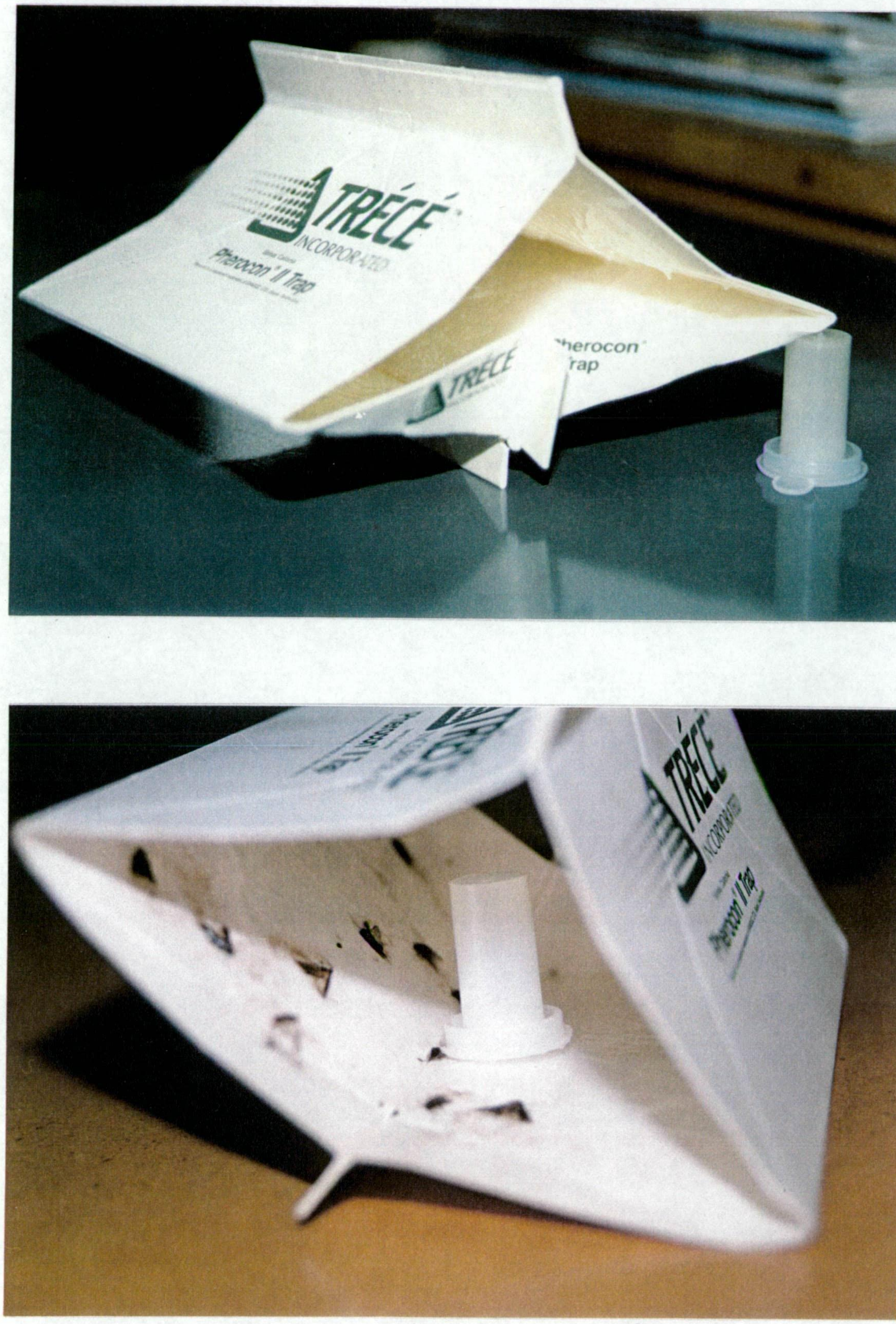


Fig. 1. Top: Pherocon II sticky trap (Trécé Inc.) and pheromone lure (International Pheromone Systems Ltd.). Bottom: Position of lure within trap and resultant *Ephestia cautella* catch.

Fig. 2. Author demonstrating trap placement and removal technique.

located within a single facility except for 4 store rooms which were housed in an adjacent outbuilding. A combination of both natural and artificial lighting was used to illuminate all rooms, with the daily duration of artificial lighting dependent upon the activities undertaken within individual rooms. Both temperature and hygiene within rooms varied greatly depending on the activities undertaken.

Trap catch was generally recorded either weekly or fortnightly except on three occasions when the sampling period was 3 weeks. Trap catch was recorded more frequently in some rooms than others. For the analysis reported here, the sampling period was defined as the shortest period within which the catch from all traps was recorded. If trap catch in some rooms was recorded more than once during this period, the results were summed.

During the study, synergised pyrethrins were applied once a week to selected rooms of the factory via a 'fixed' system that delivered the pesticide through ceiling jets at a pre-determined time. In addition, the entire factory was hand-sprayed with synergised pyrethrins every 1-3 weeks.

Further details regarding 3 rooms (designated rooms X, Y and Z) are required. Room X had a floor space area of ~430m² in which the primary activity undertaken was nut roasting. Two traps were placed in the room for the entire study. Room Y had a floor space area of ~225m² in which chocolate pasting and refining activities took place. One trap was placed in the room from the beginning of the study until October 1994, when 9 traps were stationed to aid in the location of local infestations. Room Z had a floor space area of ~1430m² in which a number of activities took place including the melting of cocoa and cocoa butter mass, chocolate refining, powdered cocoa and drinking chocolate production and waste re-working. Nine traps were placed in the room from the beginning of the study until the end of July 1994, when a mass trapping study began in this room, and the number of traps was significantly increased (see below). Rooms X, Y and Z are clearly identified in Appendix VII.

To determine the distribution of males throughout the factory at each sample, the frequency distribution of the number of males captured in each room was analysed for its goodness of fit to mathematical models that have been proposed to describe the distribution of organisms in space (Southwood 1978). Green's (1966) index of dispersion was calculated to describe the degree of contagion of the population. Myers (1978) found that Green's index provides a good measure of dispersion without being influenced by population density. Green's index ranges from 0, representing random dispersion, to 1, representing a high degree of contagion.

Stepwise regression analysis was used to determine the factors responsible for the distribution of males within the factory. Six independent variables were tested against the total number of males captured in each room during the study. The trap catch data was transformed using log(x+1) to stabilize variances (Zar, 1984). The six variables used to categorise each room were: (1) the standard of hygiene (good or poor); (2) the presence or absence of temperature control; (3) the presence or absence of a 'fixed' pyrethrin release system; (4) the presence or absence of available water; (5) the number of traps per area (m^2) [the mean number of traps was used when trap numbers varied during the study] and; (6) the shortest, straight-line distance (m) of each room from room Z.

A room was scored as having a 'good' standard of hygiene if machinery was cleaned regularly and debris, and/or waste product, was not permitted to accumulate or stand for long periods. Rooms that were not regularly cleaned, resulting in the obvious accumulation of debris within the room, and/or on machinery, were scored as having 'poor' hygiene. Rooms in which waste product, or product to be re-worked, was allowed to stand for long periods (2-3 months) were also scored as having a 'poor' standard of hygiene. Rooms were scored as having 'available' water present if pools of water were consistently observed in a room during the study. This generally only occurred in rooms that incorporated areas for washing equipment, although the leakage of water from machinery also resulted in pools of water consistently being formed in some areas.

To determine the effectiveness of hand-spraying synergised pyrethrins to control *E. cautella*, the mean capture rate (males/trap/week) following treatment with pyrethrins was compared to the mean capture rate following no such treatment. Samples were categorised as 'treated or 'non-treated' only if either condition occurred uniformly during the sample. For example, if a sampling period was two weeks, pyrethrin had to be applied both weeks for the sample to be categorised as 'treated'. Likewise, if no hand-spraying took place, the sample was categorised as 'non-treated'. If hand-spraying occurred only once during a two week sampling period, the sampling period was excluded from the analysis.

4.2.2 Mass trapping study

The study was conducted from August 1994 to June 1995 in the room previously designated 'room Z'. Pherocon II sticky traps were again used for the trial, except towards the end when four black stripe moth traps (AgriSense, UK) replaced four of the sticky traps placed in a particularly dusty area of the room. Based on results of Bowditch *et al.* (1994), it was assumed that the introduction of the stripe traps did not significantly influence subsequent trap catch. IPS pheromone lures were used in all traps.

Initially, 50 traps were deployed at a rate of approximately one every $100m^3$. The position of each trap and the number of males captured in each is shown in Appendix VIII. This was a higher trapping density than had previously been recommended to suppress phycitines (Trematerra and Bataini, 1987), but given the highly ventilated nature of the room (doors were often left open for long periods) it was decided that additional traps were necessary. Later in the study, the number of traps was increased to 90, approximately one trap every $49m^3$. The position of each trap and the number of males captured in each is shown in Appendix IX.

The traps were hung from overhead piping in a grid formation where possible. The pheromone lures were replaced every 8-10 weeks, and traps renewed when they became ineffective due to moth or dust accumulation. Trap catch was recorded each week except on three occasions when the sampling period was 2 weeks. The room was hand-sprayed with synergised pyrethrins every 1-3 weeks. No attempt was made to remove or clean up *E. cautella* infestations during the study, and there was believed to be negligible immigration of *E. cautella* into this room from other areas.

Unfortunately, no room suitable to act as a control for this study could be located either on the factory site or offsite. Consequently, to assess the treatment, results were compared with monitoring data collected from naturally occurring *E. cautella* populations in other areas of the factory, and to monitoring data collected from the this room prior to the commencement of the mass trapping study. No independent method of sampling was undertaken in the treatment room to verify apparent changes in population density exhibited in the trapping data.

4.3 RESULTS

4.3.1 Pheromone monitoring study

Populations of *E. cautella* were highly restricted within the factory with the majority (81%) of males captured in only 3 of the 35 rooms sampled (Table 1). These rooms represented only 9% of the total trapping area. Less than 10 males were captured in more than half of the rooms, and no males at all were trapped in 7 rooms during the study.

Table 1. Frequency of *Ephestia cautella* captured per room within the factory from March 1994 to March 1995.

Males/room	No. Rooms	No. Males (%)
0	7	0 (0)
1-10	19	76 (7)
11-50	6	139 (12)
>50	3	924 (81)
Total	35	1139 (100)

Of the three rooms in which a large number of males were captured (rooms X-Z; Fig. 3a-c), only in room X did the number of traps remain constant throughout the study. In this room, two clear population peaks were observed in December 1994 and February 1995. Males were captured in all but three samples, although very few were caught between April and September, and 15% of all males captured in the factory were caught in room X. In room Y, no males were captured from early April to early July, and again in late July. Population numbers began to increase in August, and continued to increase until the end of the study. 20% of all males were captured in room Y. Except for one sample in April, males were consistently captured in room Z

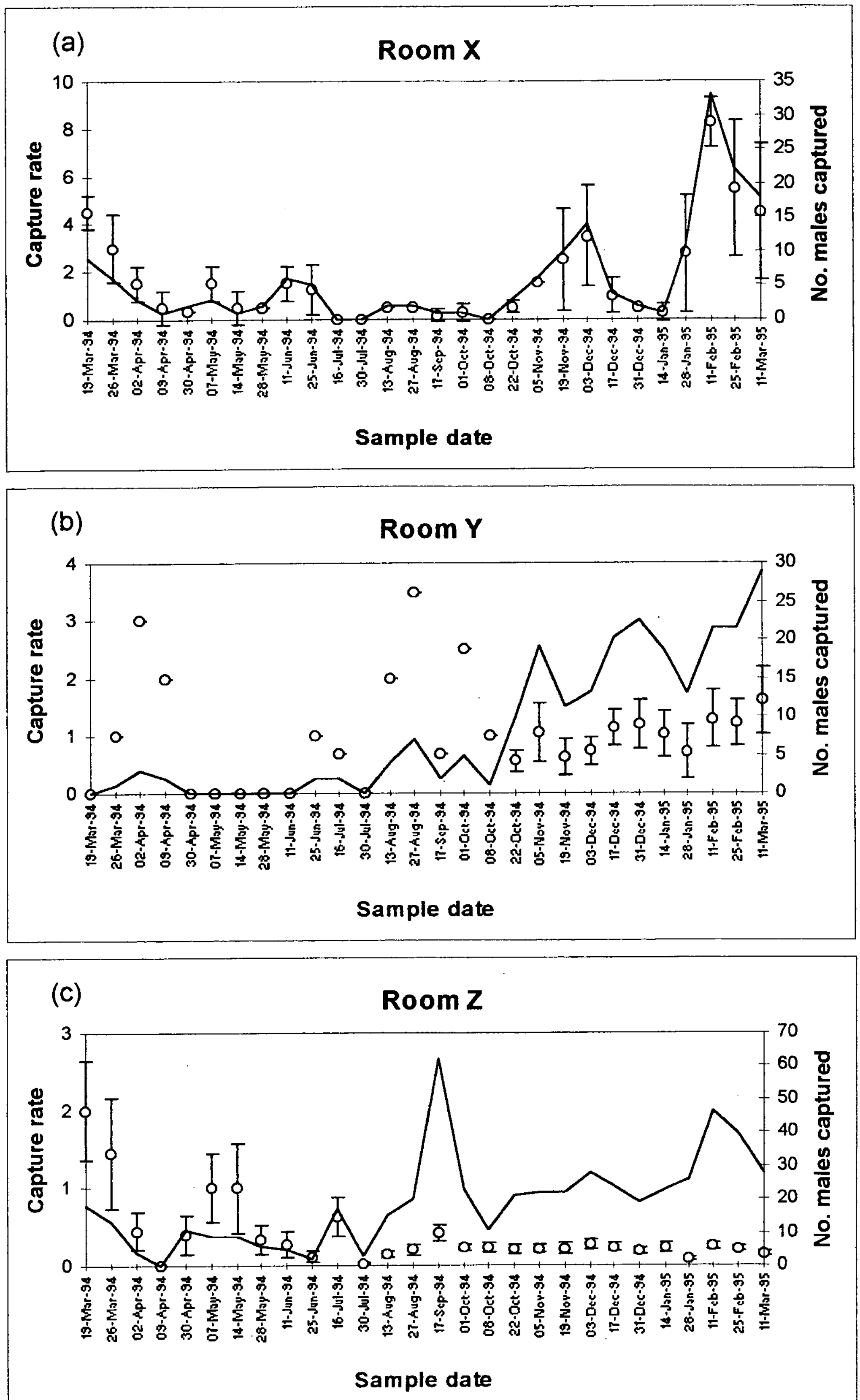


Fig. 3. The mean (±SE) number of *Ephestia cautella* males captured, and the capture rate (males/trap/week) in (a) room X, (b) room Y and (c) room Z from March 1994 to March 1995.

throughout the study. The presence of a high number of traps in room Z (due to mass trapping activities) resulted in a low capture rate being recorded for most of the study. Of all males trapped, 46% were captured in room Z.

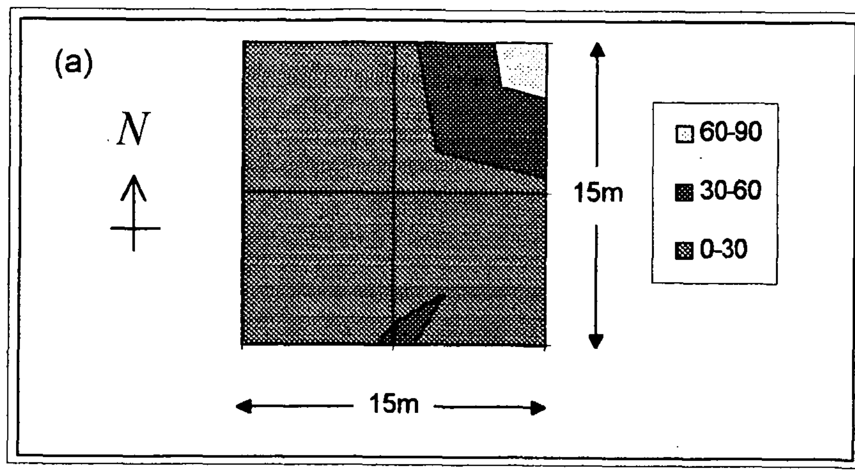
Males were distributed throughout the factory in a contagious pattern during the majority of sampling periods (Table 2). Only on 3 occasions did the observed frequency distribution fail to fit the negative binomial model, which is indicative of a contagious distribution (Southwood 1978). Green's (1966) index of dispersion revealed a degree of variation in aggregation over time, with the often high index values emphasising the highly restricted distribution of the population.

Within individual rooms, *E. cautella* distribution was also generally restricted, with males consistently captured only in particular areas. These areas were nearly always associated with larval rearing sites which were readily located by inspecting around the trap(s) that captured the most adult males. For example, in room Y, most males were captured by a trap placed in the NE corner (Fig. 4a). Following an inspection of this area, debris infested with *E. cautella* larvae was located behind an electrical panel. A number of males were also captured at the southern end of the room, above a wash area although no infestation site was located. In room Z (Fig 4b), most males were captured at the eastern end of the room, where twin chocolate refining machines (Fig. 5) were found to be infested. Traps placed directly above these machines captured the most males with traps placed around the refiners capturing slightly fewer males. Three areas of high *E. cautella* activity were also located at the western end of room Z. The patch near the northern wall was associated with an infested shredding machine (Fig. 5), while the other two patches were associated with infested metal guards that encased gearing equipment.

Analysis revealed that the standard of hygiene explained most variation in the number of males captured throughout the factory, with fewer males captured in areas where good hygiene practices were maintained (Table 3). Significantly more variation was explained if the 'distance from room Z' was added to the equation, with the catch rate being negatively correlated with increasing distance. These two variables explained 47% of the variation in trap catch between rooms. The other factors (the presence or absence of temperature control; the presence or absence of a 'fixed'

Table 2. The mean, variance and goodness of fit to a negative binomial distribution of the number of *Ephestia cautella* males captured per room at each sample date. Green's index (GI) indicates the degree of dispersion.

Date	$\bar{x}$	s^2	χ^2	GI
19/03/94	1.086	11.904	3.08 ns	0.269
26/03/94	0.657	5.879	0.84 ns	0.361
02/04/94	0.571	1.193	0.42 ns	0.057
09/04/94	0.229	0.299	0.57 ns	0.044
30/04/94	0.543	3.785	0.85 ns	0.332
07/05/94	0.743	2.726	0.32 ns	0.107
14/05/94	0.457	2.432	2.92 ns	0.288
28/05/94	0.457	1.491	2.76 ns	0.151
11/06/94	0.600	2.012	0.64 ns	0.118
25/06/94	0.371	1.123	2.26 ns	0.169
16/07/94	0.714	8.328	2.78 ns	0.444
30/07/94	0.286	0.563	3.98 ns	0.108
13/08/94	0.771	9.652	0.41 ns	0.443
27/08/94	1.029	12.440	10.09 **	0.317
17/09/94	2.086	109.434	0.30 ns	0.715
01/10/94	0.429	1.017	0.23 ns	0.098
08/10/94	1.114	32.869	14.33 ***	0.750
22/10/94	1.143	15.244	0.86 ns	0.316
05/11/94	1.457	22.844	0.79 ns	0.294
19/11/94	1.229	18.064	1.19 ns	0.326
03/12/94	1.771	29.534	2.44 ns	0.257
17/12/94	1.486	25.081	1.06 ns	0.311
31/12/94	1.714	29.034	0.89 ns	0.270
14/01/95	1.486	28.022	2.67 ns	0.350
28/01/95	1.714	26.092	1.05 ns	0.241
11/02/95	3.086	90.139	5.92 ns	0.264
25/02/95	2.829	75.264	2.77 ns	0.261
11/03/95	2.486	51.551	7.29 *	0.230



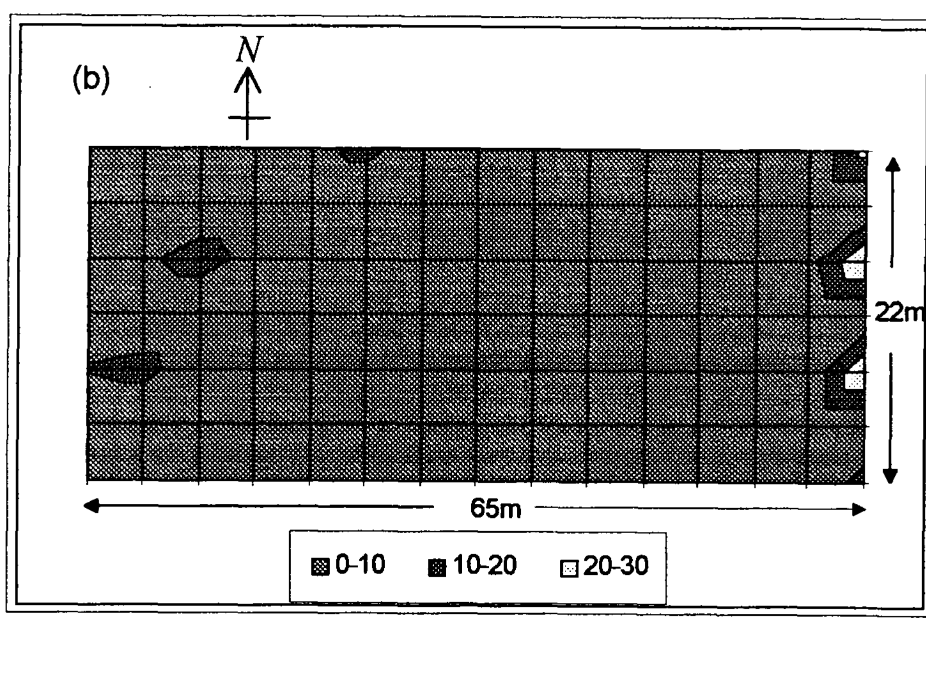


Fig. 4. Distribution of *Ephestia cautella* males captured in (a) room Y from October 1994 to March 1995 (9 traps), and (b) room Z from July 1994 to January 1995 (50 traps).

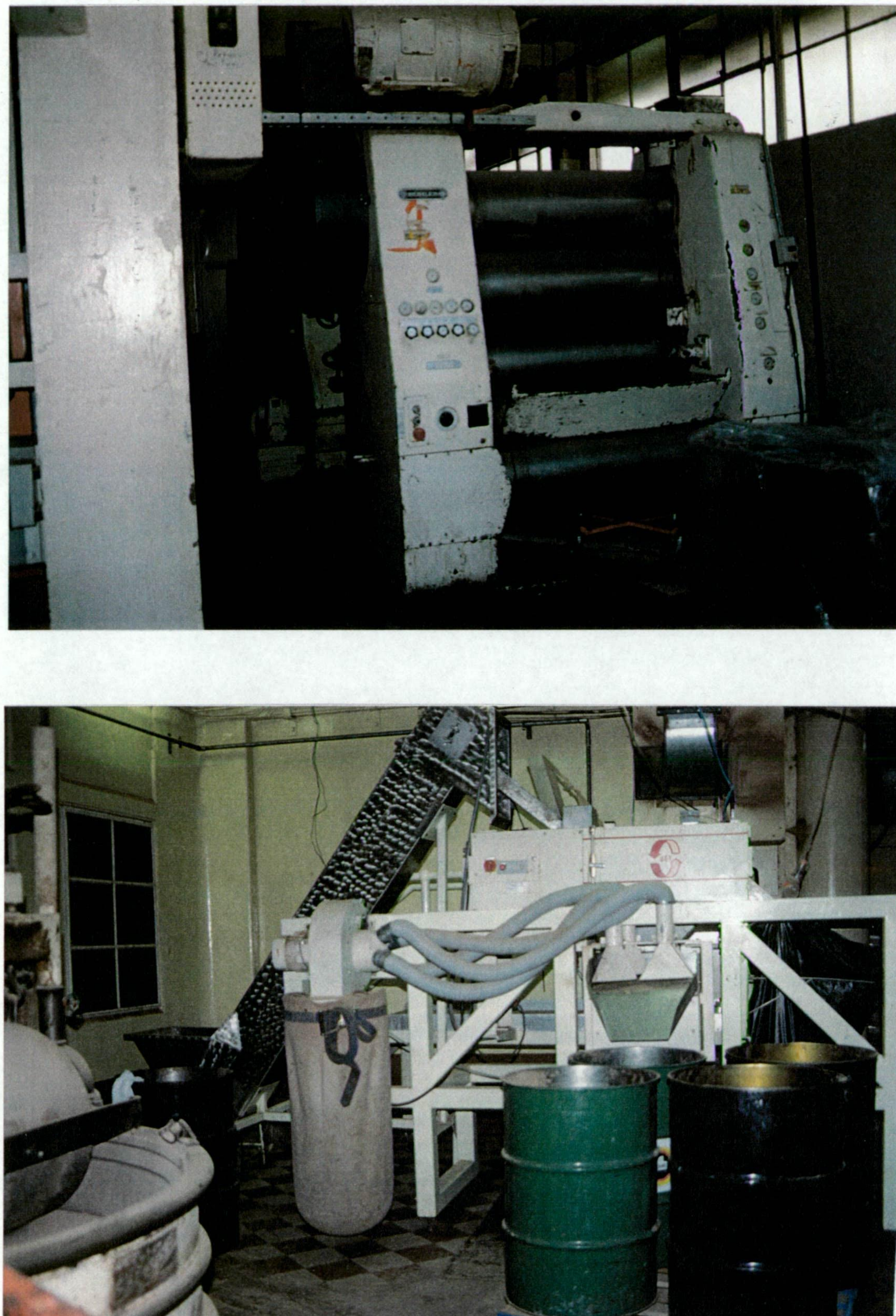


Fig. 5. Machinery in room Z found to be infested by *Ephestia cautella*. Top: twin chocolate refiners; Bottom: shredder.

pyrethrin release system; the presence or absence of available water and; the number of traps per area (m^2)) did not significantly influence *E. cautella* distribution.

Table 3. Stepwise regression analysis of the factors that influence the distribution of *Ephestia cautella* males throughout the factory where: h = hygiene; d = distance (m) from room Z and, x = number of males captured per room.

Step	Variables	Regression equation	r^2
1	h	$\log(x+1) = 0.391 + 0.844h$	0.374
2	h + d	$\log(x+1) = 0.746 + 0.700h - 0.015d$	0.468

The schedule of hand-spraying carried out during the study, and the associated capture rate of *E. cautella* are shown in Fig. 6. The mean capture rate throughout the factory following treatment with pyrethrins was not significantly different from the capture rate when pyrethrins were not applied (Two-sample t-test: $t = 1.900$, $df = 9$, $P>0.05$). This result was not influenced by seasonal factors as there was no significant difference between the mean capture rate during spring/summer (September-February) and autumn/winter (March-August) (Two-sample t-test: $t = 1.756$, $df = 24$, $P>0.05$).

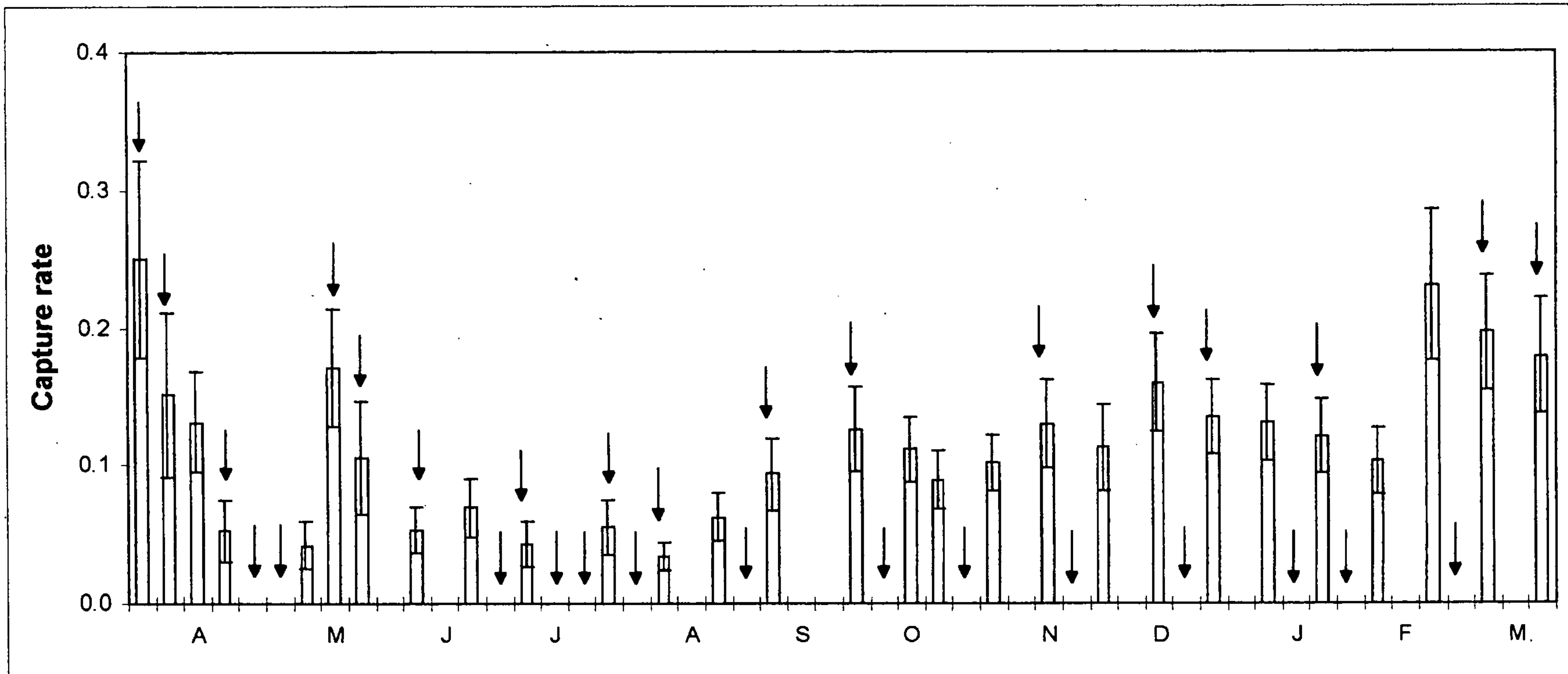


Fig. 6. Mean (±SE) capture rate (males/trap/week) of *Ephestia cautella* at Claremont from March 1994 to March 1995. The arrows indicate the weeks during which synergised pyrethrins were applied.

4.3.2 Mass trapping study

A total of 522 *E. cautella* were captured during the mass trapping study, and males were caught during each sample period (Fig. 7). The room remained consistently warm (29±4°C) throughout the study, which provided excellent conditions for *E. cautella* growth and development. Temperatures peaked during the summer months (December to February), but there was no accompanying peak in trap catch. This is contrary to the trends evident in rooms X and Y where trap catch did peak over summer (see Fig. 3).

The increase in trap numbers from 50 to 90 failed to result in the capture of more *E. cautella* (Fig. 7). In fact, 9 weeks after the increase in trap numbers, the number of males captured decreased markedly, and remained at low levels for the remainder of the study. When the number of males captured during this period (mid-March to early June) was compared with the number of males over the same period the year before, it was found that fewer males were captured despite using ten times the number of traps (Table 4). Assuming that conditions in the room were similar over both years, and that 90 traps will catch more males than 9 traps (both of which are reasonable assumptions), this suggests that mass trapping significantly reduced the population compared to the year before.

Table 4. Number of males captured in room Z from mid-March to early June in 1994 and 1995.

Year	No. traps	No. males	Capture rate (males/trap)
1994	9	80	8.89
1995	90	73	0.81

The *E. cautella* capture rate (males/trap/week) within the room decreased over the course of the study (Fig. 8). The capture rate peaked in early September and then fluctuated at a rate between ~0.15 and 0.3 males/trap/week until mid-March, when the rate declined, as a result of the decrease in the number of *E. cautella* captured, and remained at below 0.15 males/trap/week for the remainder of the study.

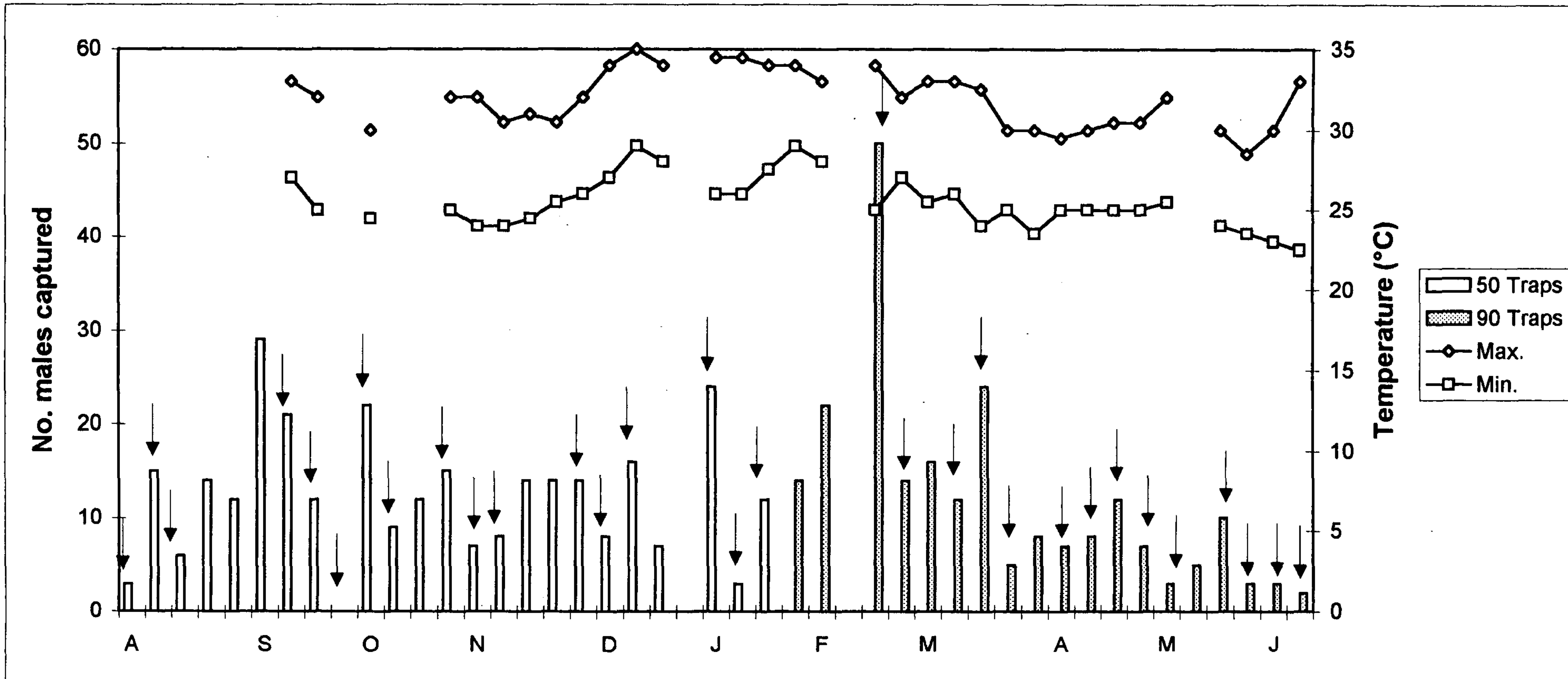


Fig. 7. The number of *Ephestia cautella* captured in room Z from August 1994 to June 1995 during a mass trapping experiment. The maximum and minimum temperatures recorded in the room are shown, and the arrows indicate the weeks during which synergised pyrethrins were applied.

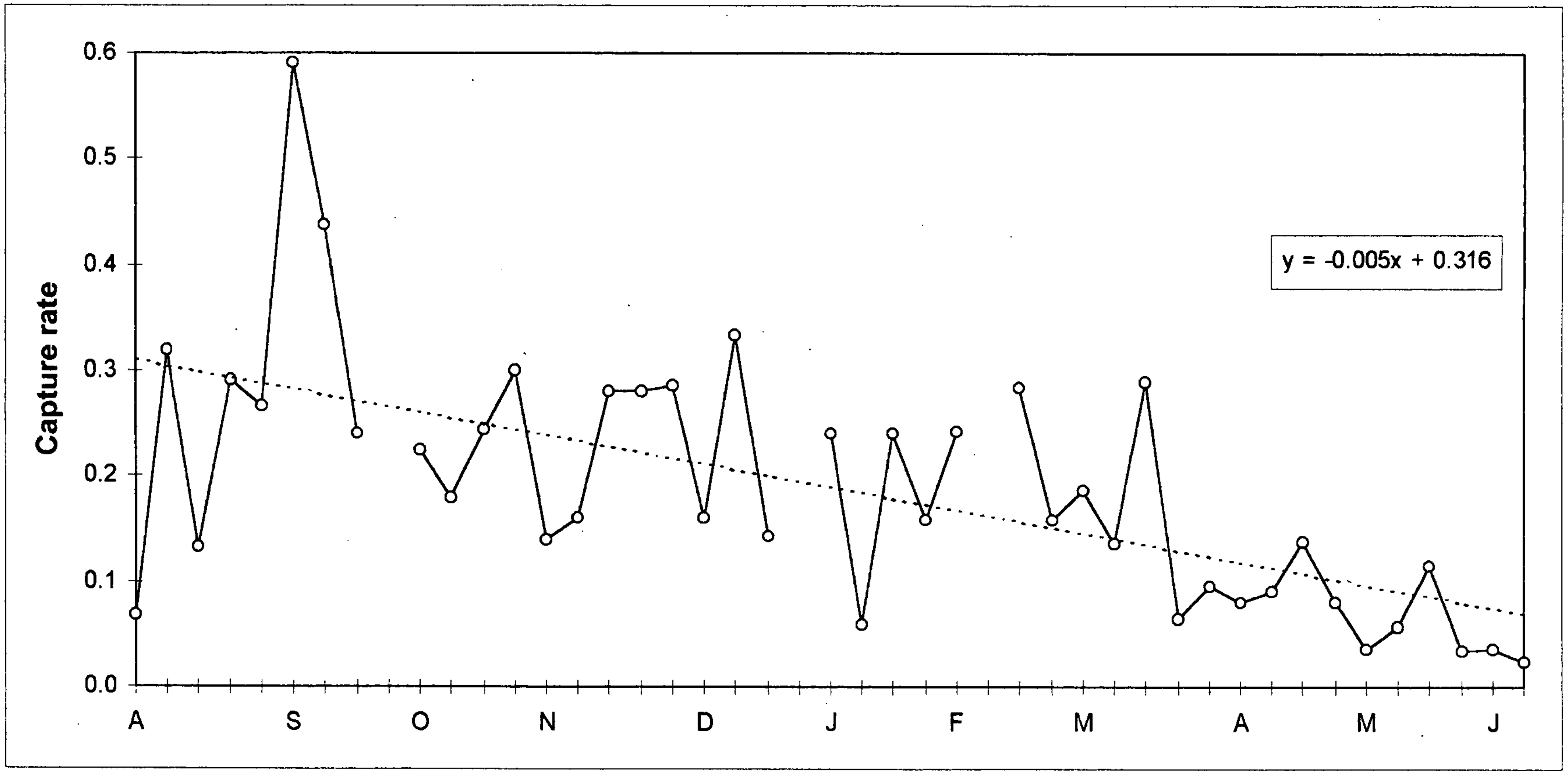


Fig. 8. The capture rate (males/trap/week) of *Ephestia cautella* in room Z from August 1994 to June 1995 during a mass trapping experiment. The dashed line and associated equation represent the linear capture rate trend.

The weekly capture rate was only weakly correlated ($r = 0.45$) with the average weekly temperature ([max. + min.] / 2), and analysis of variance revealed that the 'age' (in weeks) of the pheromone lures did not significantly influence the capture rate ($F = 0.704$, $df = 40$, $P>0.05$).

4.4 DISCUSSION

4.4.1 Pheromone monitoring study

Although the management *Ephestia cautella* via pheromone trapping and infestation removal was unable to be comprehensively evaluated, due to the continual application of synergised pyrethrins and the absence of sanitation support, the results of this trial suggest that this strategy provides a viable alternative to the blanket application of synergised pyrethrins. Pheromone trapping provided a non-intrusive method of monitoring *E. cautella* that was cost effective (see Chapter 6) and simple to operate and maintain. It also aided in the location of cryptic larval development sites, despite the presence of alternative attractants, which occasionally provided misleading indicators. The high number of males captured at the southern end of room Y, for example, were thought to have been drawn there by the presence of water, an *E. cautella* attractant (Chow *et al.*, 1977). The usefulness of aggregated pheromone traps to locate insect pest development sites has been reported previously (e.g. Pierce, 1994; Vick *et al.*, 1986).

It is possible that had the identified larval rearing sites been removed, a significant proportion of the developing population may have been eradicated due to the observed tendency of *E. cautella* females to continually reinfest the same sites. It is likely that gravid female *E. cautella* prefer to oviposit on a food source contaminated by conspecific larvae, as this is a trait common to other storage moth species (Corbet, 1973; Phillips and Strand, 1994). By removing existing larval development sites, and improving hygiene standards generally in certain factory areas, *E. cautella* could potentially be eradicated from the entire factory. The removal of debris from large, complex machinery may occasionally prove impractical. In such cases, fumigation, or some other such treatment, will be necessary to eradicate local infestations.

The consistently contagious distribution of *E. cautella* within the factory emphasised the highly restricted nature of populations. During each sample period, most rooms remained free of *E. cautella*. Indeed, most males were captured in only three rooms and, in two of these, high numbers were only recorded for part of the year. This suggests that that repeated blanket applications of synergised pyrethrins throughout the entire factory were unnecessary and that much of the pesticide was wasted. If control measures had been appropriately targeted, pesticide usage could have been reduced by as much as 80-90%, thereby providing significant cost savings and reducing the risk of contamination.

The finding that the distribution of *E. cautella* within the factory was primarily dependent upon hygiene standards was not surprising. The importance of maintaining good hygiene conditions has long been recognised as of primary importance for controlling insect pests within a confectionery plant (Anon., 1969). Improving sanitation management in the rooms identified in this study as having 'poor' hygiene standards, offers the key to reducing the distribution of *E. cautella* within the factory.

The presence of a 'fixed' pyrethrin release systems in various rooms of the factory failed to influence *E. cautella* distribution, and the hand-spraying of pyrethrins did not significant reduce male capture rate. A number of factors are thought to have contributed to the failure of synergised pyrethrins to control *E. cautella*. Firstly, fogging with synergised pyrethrins will only affect exposed insect stages. Most *E. cautella* growth and development occurred within refuges where the pesticide may not have penetrated. Only the winged adult and occasionally, wandering late instar larvae were exposed. Secondly, treatment did not coincide with peaks in adult activity which occur at dawn and dusk (Madrid and Sinha, 1983; Steele, 1970). Thirdly, the poor sealing of many rooms lead to incomplete coverage and short 'hang' times which, presumably, led to sublethal doses being applied. Resistance is suspected but, as yet, has not been confirmed. Resistance to synergised pyrethrins has been recorded in a number of insect pest species (e.g. Cline *et al.*, 1984; Meyer *et al.*, 1990), and Zettler (1973) found low levels of resistance to synergised pyrethrins in *E. cautella* strains collected from peanut and grain storage facilities. Fourthly, in most areas of the factory, the system operated only once a week, resulting in a 7 day period between applications. This is sufficient time for significant copulation and oviposition behaviour to occur between newly emerged adults; *E. cautella* females will copulate within hours of emergence and realise maximum oviposition on the second day after emergence (Steele, 1970). Fifthly, at times of peak production, access for hand-spraying, even at weekends, was prevented leading to long periods between applications. At these times, the automatic pyrethrins release systems were also often disabled.

Controlling *E. cautella* in room Z was clearly a priority as this was the only area in which the continuous development of *E. cautella* occurred throughout the study. Activities undertaken in this room ensured that warm conditions were maintained year-round. By continuing to multiply over winter, a reservoir of individuals was available to colonise other suitable areas once conditions improved. Indeed, the proximity of a room in relation to room Z was an important factor influencing the number of males captured which infers that room Z was an important source of migrating individuals. Fortunately, the mass trapping experiment conducted in this room considerably reduced the population (see below), and, at the time of writing (December 1995) the population was still at very low levels compared with previous years (P. Newell *pers. comm.*).

The mode of *E. cautella* movement throughout the factory was thought to be via both active and passive dispersal. Although *E. cautella* was highly vagile within rooms, as previously reported by Hagstrum and Stanley (1979), little movement was observed between rooms. However, a small number of individuals were observed moving through an open doorway in room Z and up an adjoining stairwell. Passive dispersal probably occurred during the routine movement of equipment around the factory.

It is clear from the results presented in this study that the current strategy of controlling *E. cautella* at the factory, via the regular blanket application of synergised pyrethrins is incapable of delivering the goal of an insect pest-free environment and, therefore, insect pest management needs to be re-evaluated. A proposed alternative strategy to manage *E. cautella* and other insect pests resident at the factory, which relies primarily on improved hygiene management, is presented in detail in Chapter 6.

4.4.2 Mass trapping study

Mass trapping successfully suppressed the *E. cautella* population throughout the study, reducing the overall population, and preventing the expected population increase over summer (December to February) that was evident in other rooms of the factory. Had the study been extended, it is likely that *E. cautella* would have been completely eradicated from room Z, thereby significantly reducing the risk of product infestation at the factory.

While other instances of phycitine suppression by mass trapping have been reported previously (Pierce, 1994; Šifner *et al.*, 1983; Süss and Trematerra, 1986; Trematerra and Bataini, 1987), the degree of control achieved by pheromonal manipulation has been indistinguishable from that achieved through other control techniques such as infestation removal. In this study, no such sanitary procedures were undertaken, however, the application of synergised pyrethrins may have aided control.

Increasing the number of traps from 50 to 90 in January was thought to have been responsible for the decline in *E. cautella* numbers apparent from mid-March. While increasing the number of traps did not remove considerably more males from the population, the additional pheromone in the environment probably increased mating disruption and, consequently, after a short lag period, further reduced the *E. cautella* population. The mechanisms of mating disruption are not fully understood but control could be due to the synthetic pheromones out-competing females, or sensory adaptation or habituation in male insects (Birch and Haynes, 1982). Whatever the mechanisms involved, mating disruption generally results in a greater proportion of virgin females within a population and fewer progeny (Brady and Daley, 1975; Haines and Read, 1977; Hodges *et al.*, 1984; Sower and Whitmer, 1977). Even if a high background level of pheromone merely delays mating, this can significantly reduce both fecundity and fertility (Barrer, 1976).

Although the results presented must be interpreted with caution due to the lack of an adequate control or independent sampling to verify apparent changes in population density, there is sufficient evidence to suggest that mass trapping not only suppressed the *E. cautella* population, but also reduced the population over the course of the study. However, while the mass trapping technique is clearly a useful strategy to suppress phycitine populations in environments such as that found within the factory, strategies such as infestation removal or fumigation will lead to more rapid control. Therefore, within the factory, mass trapping will probably only prove practical to use in areas where these other strategies prove to be either impractical or unsuccessful, or in factory areas where the presence of phycitines is not seen as a direct threat to finished product in the short to medium term.

CHAPTER 5

Aspects of phycitine ecology in regard to post-packaging infestation of chocolate-based consumables

5.1 INTRODUCTION

Investigations into the origins of phycitine infestation of chocolate-based consumables manufactured at Cadbury Schweppes' Claremont factory revealed that most infestation occurred after produce had been packaged. Previous studies into the insect contamination of packaged foodstuffs have primarily concentrated on the preventative role played by product packaging. A number of studies have examined the resistant properties of various types of flexible, polymer packaging films (either singly or in combination) against a variety of stored product insect pests (Cline, 1978; Gerhardt and Lindren, 1954,1955; Highland and Jay, 1965; Highland and Wilson, 1981; Highland *et al.*, 1968; Rao *et al.*, 1972; Yerington, 1975). Other have investigated the protective properties of insecticide-treated films (Highland and Cline, 1986; Highland *et al.*, 1986), while the relationship between infestation and package integrity has also been examined (Mullen and Highland, 1988; Yerington, 1978).

Little attention, however, has been paid to the processes involved in insect pest recognition and location of packaged goods prior to invasion. Highland (1984) stated that "infestation probably is a consequence of searching, exploratory activities of the insects, and the subsequent discovery of food that is suitable for nourishment and reproduction". However, whether these activities are driven primary by chance, or whether stored product insects utilize environmental cues to promote these searching activities, has been little investigated.

Examined in this Chapter are a range of factors involved in the recognition, location and invasion of packaged chocolate-based consumables by phycitine moths. The role that odour plays in adult and juvenile searching behaviour is investigated, and other factors thought to be important in the infestation process, such as package integrity, and the resistance properties of packaging materials, are also investigated.

5.2 MATERIALS AND METHODS

5.2.1 Oviposition behaviour of *Ephestia cautella* and *Plodia interpunctella* in response to odours from chocolate-based consumables

(i) Cage experiment

This experiment was undertaken to determine whether free-flying *Plodia interpunctella* females would preferentially oviposit near an odour source which, in this case, was a box of chocolates. The experiment was carried out in a cage (60 x 60 x 60cm) whose base and sides were constructed of wood, and front and top constructed of Perspex. A sealable lid was fitted to the roof of the cage and a cloth 'sleeve' to the front. The cage contained three horizontal shelves at 15, 30 and 45cm above the floor. The shelves ran along the entire back and half way along the sides of the cage. The cage was housed in 25(±1)°C constant temperature room. The lighting regime was 16L:8D with 'lights-off' at 2100. Relative humidity was not controlled.

Boxes of the assortment variety '250g Roses' was used in the experiment because this variety is most often infested by phycitines (see Chapter 3). The thin cardboard boxes are constructed by placing a series of flaps into pre-cut slots; no sealant is used. The entire top of a box is designed as a flap that opens to reveal the contents. The dimensions of the box are 17 x 10.3 x 4cm. Placed within each box are 24 individual units, generally two of each of the twelve assortment varieties included. Each unit is encased in foil that is 'twist' wrapped around the unit but not sealed. After the boxes are constructed and filled, they are overwrapped, by machine, with a polyvinyl chloride (PVC) shrink-wrap (25µm) that is self-sealing upon the application of heat. The overwrapping process involves wrapping a section of film around the box and heat-sealing the two edges along the base of the box. The overwrap is then folded over the ends of the box, in an envelope-type fold, and heat-sealed. The boxes are then passed through a heat tunnel to shrink the overwrap slightly and produce a neat, tight finish. Although wrapped tightly around the cardboard box, the overwrap is not attached to the box in any way. Fig. 1 shows the overwrapping process in progress, and the heat tunnels.

Fig. 1. Equipment used to overwrap assortment products (top) and the heat tunnels used to shrink the overwrap around the boxes (bottom).

Six boxes of 250g Roses were used in the experiment, all of which were fumigated with methyl bromide prior to overwrapping, although their contents were not standardised. In 3 boxes, a 2mm (diameter) hole was made through the overwrap at each end of the box with a heated metal probe. The holes were positioned centrally near the top of the vertical box ends where the upper flap (the lid) of the box is folded over the contents. There is usually a 2-3mm space between the lid and the ends of the box at this point, and it was decided that positioning the holes in these space would maximise odour release. Around each hole were drawn concentric rings (1cm apart) to a distance of 4cm in order to quantify how close to the odour source (the hole) eggs were laid (Fig. 2a). These boxes were designated as 'fault' boxes. Three 'control' boxes, that had no visible (to the naked eye) ruptures or tears in the overwrap, were also placed into the cage. A single control and treatment box were placed on each shelf. Under each box was placed a black cardboard tray (21.6 x 27.9cm) in order to identify eggs laid in the immediate vicinity the boxes (Mullen, 1994). The boxes were placed centrally on the trays and the trays were placed toward the back of the cage. The experimental set-up before the front of the cage was repositioned is shown in Fig. 2b.

The boxes remained in the cage for 24h after which 30 (15 male + 15 female) adult *P. interpunctella* were introduced at ~1500. The adults, of unknown age, were taken from existing *P. interpunctella* cultures reared on a diet of kibbled wheat, glycerol and brewer's yeast (10:2:1 by parts (Bell, 1975)). 48h after the moths were released into the cage, the boxes and trays were removed and number of eggs laid, and their position, was recorded. Eggs deposited on the tray were categorized as either being laid at the end of the box facing the rear of the cage, or as being laid at the end facing the front of the cage, depending on which end they were closest to. If eggs were attached to the boxes, the end at which they were attached was likewise recorded. Eggs attached to the fault boxes were categorized as being deposited either 0, 1, 2, 3, 4 or >4cm from the holes made through the overwrap at each end of the boxes. Eggs laid through these holes were categorized as being laid 0cm from the odour source. No attempt was made to quantify the number of eggs laid in other areas of the cage. The experiment was replicated 3 times.

Fig. 2. Set up of 'cage' oviposition experiment: Top - concentric rings drawn around an artificially made hole in the overwrap at each end of a box 250g ;Bottom - placement of fault (holes in overwrap) and control (no holes) boxes on black cardboard trays within the cage.

Three-factor analysis of variance was undertaken to determine the influence of: (1) treatment (fault or control); (2) shelf (upper, middle or lower) and; (3) box end (end facing front of cage or end facing rear of cage) on the number of eggs laid. Variances were stabilized by transforming the data by 'log (x + 1)' where x was the number of eggs laid.

(ii) Chamber experiments

A second method of examining phycitine oviposition responses to food odours was also undertaken. This involved placing moths in a small chamber (that had a mesh base and lid) over an odour source, so that while the moths were confined, odours were allowed to pass freely through the top of the chamber.

The chamber (Fig. 3a) was constructed from a plastic container (12cm diameter, 10cm height) whose base and top were removed and replaced with wire mesh (1 x 2mm). The chamber rested on top of two vertical outlet tubes (3cm diameter, 4.5cm height) that ran from two separate, sealed containers (15 x 20cm). The outlet tubes were 4cm apart, and additional supports were used to stabilize the chamber. The outlet tubes protruded 0.5cm into the containers via holes cut in container lids. A thin piece of black cardboard, with circular holes cut for the outlet tubes, was placed centrally below the chamber over the two containers. A bisecting line was drawn on the cardboard to mark where the edges of the two containers met. Bisecting lines were similarly marked on the lid and base of the chamber, and the position of the two outlet tubes was also marked on the base (Fig. 3b).

A single 250g Roses box was placed into one of the containers. Immediately prior to this, the overwrap was punctured, as in the previous experiment, so that a 2mm (diameter) hole was present at each end of the box. The other container was left empty as a control. An open Petrie dish (10cm diameter) was placed into each container directly below each outlet tube to collect any eggs deposited down the tubes. In the container with the Roses box, the petrie dish sat on top of the box. In the empty container, the petrie dish rested on the floor of the container.

24h after the Roses box had been placed into one of the containers, three male and three female adults were introduced to the chamber. The adults, of unknown age,

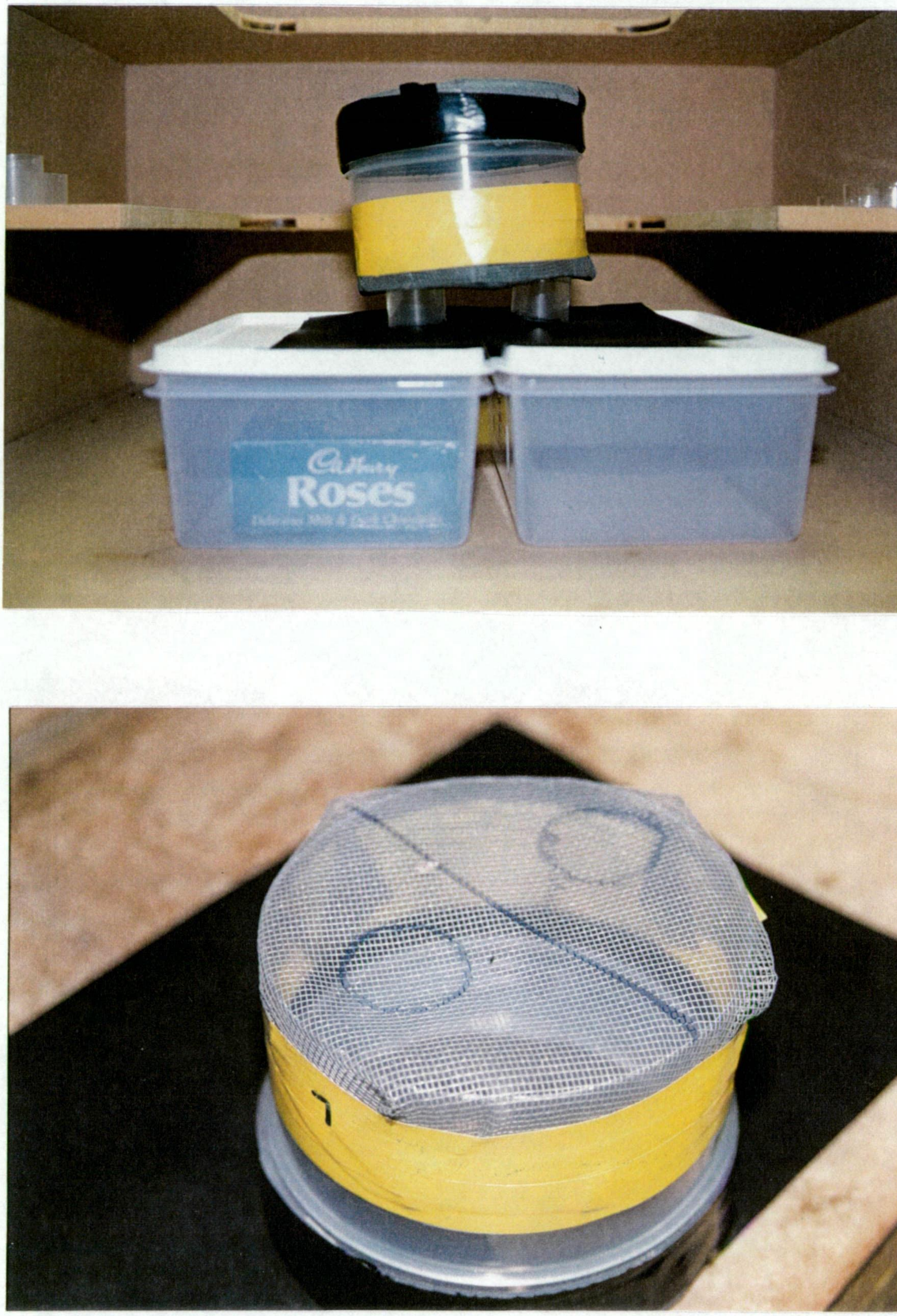


Fig. 3. Set up of 'chamber' oviposition experiment: Top - moth chamber and associated apparatus; Bottom - markings on the base of the chamber.

were taken from existing *P. interpunctella* and *Ephestia cautella* cultures reared on a diet of kibbled wheat, glycerol and brewer's yeast (10:2:1 by parts (Bell, 1975)).

48h after the introduction of the adults, the number of eggs laid, and their positions, were recorded. Where eggs were positioned by females was regarded as indicative of the female response to odours emanating from the containers below. The chamber and tray were essentially divided into two halves, with each half placed over the treatment (chocolate) odour source or the control (no odour source). Those eggs laid in the half of the chamber or tray placed over the treatment odour source were regarded as a female response to the chocolate odours. Those eggs laid in the half of the chamber or tray placed over the control container were regarded as a female response to the empty container. While eggs were primarily categorised as to which half of the apparatus they were deposited, they were further categorized according to which surface they were deposited on. Eggs were categorized as being laid: I - on the tray; II - through the treatment outlet tube and into the petrie dish; III - on the (mesh) chamber lid; IV - on the basal mesh of the chamber directly over the treatment outlet tube or; V - on the basal mesh excluding the area directly over the outlet. It was assumed that any volatiles that emanated from the packaging or the plastic components of the apparatus did not influence oviposition behaviour. It was also assumed that the Roses box, visible down the outlet tube, provided no optical stimulus for ovipositing females. *E. cautella* is not attracted to the colour blue, the most obvious colour on the boxes visible down the outlet tube (Quartey and Coaker, 1992).

The experiment took place in a room where temperature (25±5°C) and relative humidity (55±10%) were only partially controlled, and the lighting regime was 16L:8D with 'lights off' at 2100. The experiment was replicated 8 times with *P. interpunctella* adults and 4 times with *E. cautella*. The container housing the box of chocolates was alternated, and all apparatus was thoroughly cleaned at the end of each replicate.

Paired-sample t-tests (Zar, 1984) were used to determine the differences in the number of eggs laid on the tray, in the containers, on the chamber lid and, on the chamber base (over and around the outlet) in response to the two odour sources (chocolates or none). Variances were stabilized by transforming the data by 'log (x + 1)' where x was the number of eggs laid.

An additional experiment using the apparatus described above was undertaken to determine the oviposition preferences of female *P. interpunctella* in response to 250g Roses boxes that had either faulty or intact overwrapping. The experiment was carried out as above, with a single 250g Roses 'fault' box (overwrap artificially punctured) placed into one container, but instead of the other container remaining empty, a 250g Roses box with no apparent (to the naked-eye) tears or ruptures in the overwrap, was introduced. Response were recorded and analysed as above, and experiment was replicated 4 times.

5.2.2 Orientation and movement of newly-hatched *Ephestia cautella* and *Plodia interpunctella* larvae in response to light and/or food odours

A series of experiments were undertaken to determine the response of newly hatched phycitine larvae to light and/or food odours. The apparatus illustrated in Fig. 4 was used in all larval orientation experiments.

The apparatus consisted of a glass Y-tube, each arm of which was 5cm long, and the diameter of the tube was 5mm. The primary arm of the Y-tube was connected to a water vacuum pump, and the two branching arms each had a sealed plastic vial (3cm diameter, 4.5cm height) attached to each end. The branching arms of the Y-tube diverged from each other at an angle of 45°. The vials on the ends of the branching tubes had three 1mm holes evenly spaced at 2.5cm above the base of the vials to allow air to be drawn through the system. The branching tubes entered the vials at ~4cm above the base of the vials. The Y-tube was supported, and held horizontally, using a plastic vial (attached to the work bench) that had three grooves cut around the top edge in which each arm of the Y-tube rested. The silicon-based tubing used to connect the Y-tube to the water vacuum pump was transparent. A piece of black cardboard was placed beneath the Y-tube to aid in the observations of larvae. All experimentation took placed at room temperature (~21°C) in a windowless room that was free of any type of food.

Only newly hatched (<24h old) *E. cautella* and *P. interpunctella* larvae were used in these experiments. The larvae were collected by removing adult moths from

Fig. 4. Y-tube apparatus used in larval orientation trials

cultures (rearing medium: kibbled wheat, glycerol and brewers yeast (10:2:1) (Bell, 1975)) and placing them into cylindrical (20cm diameter, 30cm length) plastic containers that had detachable lids and mesh (1 x 2mm) bases. Eggs laid by adult *E. cautella* females fell through the mesh into a collecting dish placed under the container. *P. interpunctella* eggs were generally attached to the basal mesh of the container and were removed using a fine camel-hair paint brush. Following collection, the eggs were then placed into a petrie dish and incubated (25±1°C, 75% relative humidity, 16L:8D) until they hatched.

To determine the phototactic responses of newly emerged *E. cautella* larvae, a 200Lux light source (desk lamp) was placed either upwind (directly behind the vials) or downwind (directly behind the vacuum pump) of the Y-tube. The light source was placed 45cm, at an angle of 45°, from the point in the Y-tube where larvae were initially positioned. The vials on the end of the branching arms were left empty, and the flow rate through the system was 20m/s. A single larva was positioned into the primary arm of the Y-tube in a central position (2.5cm from the end and 2.5cm from the junction) using a fine camel-hair paint brush. Each larva was then given 30 minutes to move 20mm either towards or away from the light. No other light source was present in the room and no light entered from outside the room. Each larva was watched continuously and the time each took to move the 20mm was recorded. Larvae that failed to move 20mm in either direction within 30 minutes were scored as having shown no response. Larvae that failed to move at all within 10 minutes of a trial commencing were regarded as having been damaged by handling and were replaced. Trials were run consecutively and it was assumed that the activities of a larva in the Y-tube did not influence the movement of larvae subsequently placed into the tube. Chi-square analysis was used to determine whether larvae were equally as likely to move towards the light as they were to move away from the light.

To determine the orientation and movement of newly hatched *E. cautella* and *P. interpunctella* larvae in response to food odours, test material (8g of either crushed roasted hazelnuts or crushed milk chocolate) was placed into one of the vials, while the other remained empty as a control. The flow rate through the system was 20m/s. Larvae were placed singly into the primary arm of the Y-tube 10mm from the junction using a fine camel-hair paint brush. Larvae were given 30 minutes to respond to the odour. Each trial had four possible outcomes, a larva either: (1) moved 20mm downwind away from the junction; (2) moved 10mm upwind to the junction and then a further 10mm along the branching arm toward the vial containing the test material; (3) moved 10mm upwind to the junction and then a further 10mm along the branching arm toward the control (empty) vial; (4) failed to move 20mm in any direction. Larvae that failed to move from where they were placed within 10 minutes of a trial commencing were replaced. A total of 40 larvae of each species were tested for their responses to each test material. Trials, with batches of 6-17 larvae, were run consecutively and the test media was refreshed after 2 hours. It was assumed that the activities of a larva in a Y-tube did not influence the movement of larvae subsequently placed into the tube. The arms on which the 'treatment' and 'control' vials were placed on the Y-tube were randomised. The trials were undertaken in complete darkness, with overhead lighting was turned on for approximately 15 seconds every 5 minutes to determine the position of the larvae. The length of time larvae took to move the required 20mm was recorded. Twenty of the *P. interpunctella* larvae tested for their response to hazelnut odours were positioned at the Y-tube junction to determine whether the initial positioning of larvae influenced their response. In this case, the responses were scored in either of four ways: (1) the larva moved 20mm downwind along the primary arm of the Y-tube within 30 minutes; (2) the larva moved 20mm upwind along the branching arm toward the vial containing the hazelnuts within 30 minutes; (3) the larva moved 20mm upwind along the branching arm toward the control vial within 30 minutes; (4) the larva failed to move 20mm in any direction within 30 minutes. Again, larvae that failed to move from where they were placed within 10 minutes of a trial commencing were replaced. Chi-square analysis was used to determine whether larvae that moved upwind were equally likely to move towards the control vial as toward the vial containing the test material. It was assumed that any volatiles from the plastic components of the apparatus did not influence larval behaviour.

To determine the response of newly hatched *E. cautella* larvae to both odours emanating from a food source and the presence of a light source, the method above was used except, in this case, a 200Lux light source was placed upwind (directly behind the vials) of the Y-tube. The light source was placed 45cm, at an angle of 45°, from the point in the Y-tube where larvae were initially positioned (10mm from the junction). The flow rate through the system was again 20m/s. The test material used was 8g of crushed milk chocolate and larval responses were recorded as above.

5.2.3 Headspace analysis of Roses units, roasted hazelnuts and milk chocolate

The volatiles in the headspace of units contained within a box of 250g Roses was determined by gas chromatography (GC) and mass spectrometry (MS), and undertaken on behalf of the author by the Central Science Laboratory (CSL), University of Tasmania. The method used to sample the headspace is illustrated in Fig. 5. One of each of the 12 types of units contained in a box of 250g Roses was placed into a sealed glass bottle (300ml) that contained a side-arm (1cm diameter) which was sealed with a rubber septum in the lid. The foil wrappers on the units were removed prior to them being placed in the bottle. After allowing approximately 1h for equilibration, an air inlet tube (a 5cm length of GC column copper tubing) was placed through the septum and into the bottle. Also placed into the bottle, through the septum, was one end of the GC column (Fig. 5); the other end of the column was attached to the Gas Chromatograph (Hewlett Packard 5890A). Thus, a flow through system was created whereby the headspace above the units was drawn off at a constant rate (~4mL/min.).

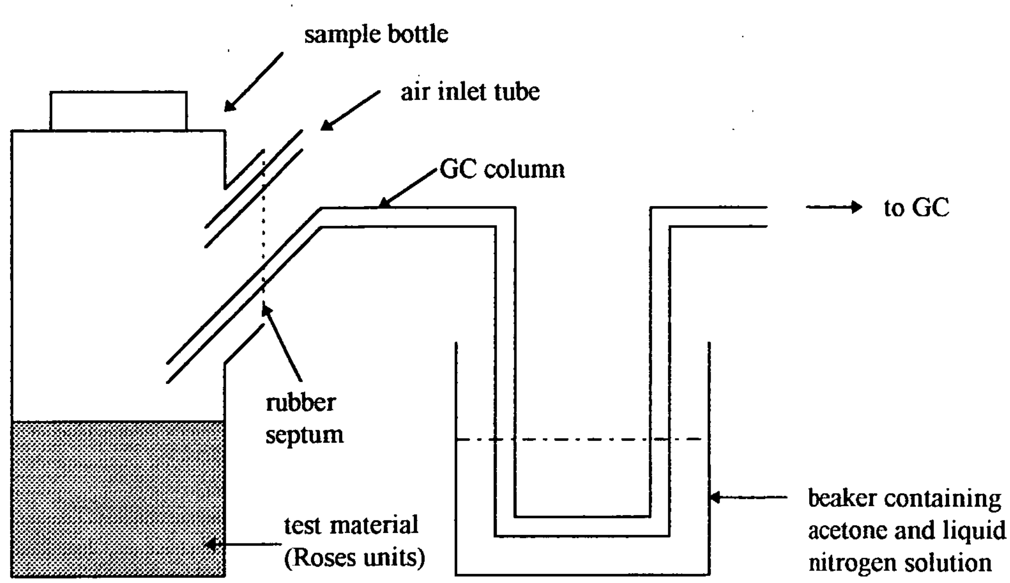


Fig. 5. Collection method used for the analysis of the headspace volatiles of Roses units (not to scale).

Approximately 180 mL of headspace was drawn from the sample and collected in a 10cm section of the column that was frozen by a combined solution of acetone and liquid nitrogen. The headspace volatiles were then identified using a Hewlett Packard 5970 Series Mass Selective Detector.

Headspace analysis of roasted hazelnuts were also determined by GC/MS on behalf of the author at the CSL. Hazelnuts were crushed (as in the larval preference trials) and enough to fill 200mL was placed in the sample bottle described above. The bottle was then heated slightly, and a syringe was used to immediately draw off the headspace above the hazelnuts. The sample was then injected directly into the GC column. A total of 27mL of headspace was sampled in 1mL aliquots. An acetone/liquid nitrogen solution was again used to trap the compounds. The same Hewlett Packard GCMS equipment described above was used for this analysis.

Analysis of the headspace volatiles of milk chocolate was conducted on behalf of the Cadbury Schweppes by the Queensland Department of Primary Industries. The milk chocolate analysed was identical to that used in larval preference trials, although the chocolate was not crushed. A 500 mL purge was collected and analysed as per the method of Wood and Aston (1994).

5.2.4 The influence of package integrity on the infestation of chocolate-based consumables by *Ephestia cautella* and *Plodia interpunctella*

(i) *Ephestia cautella*

A total of forty seven 250g Roses boxes were placed into a 60 x 60 x 60cm insect-proof cage (described previously). 23 boxes had a hole in the overwrap, and were designated fault boxes, while the other 24 control boxes had no visible (to the naked eye) ruptures or tears in the overwrap. All fault boxes had a small hole (<5mm) on one corner of the box (the corners on which the holes occurred varied). These holes occurred during the routine overwrapping of boxes during manufacture; none were made artificially.

Eight control and eight fault boxes were placed randomly onto each of the three shelves in the cage (only 7 fault boxes were placed on one of the shelves). One layer of 8 boxes (4 placed along the back of the shelf and two on each side) was stacked directly on top of another layer of 8 on each shelf. Also placed on the floor of the cage was a 4l glass jar containing 250 *E. cautella* eggs and 500g of rearing media (kibbled wheat, glycerol and brewers yeast (10:2:1)).

Three weeks after the peak emergence of *E. cautella* adults, 8 control and 8 fault boxes were randomly selected, opened and the number of larvae, pupae or adults found in each box was recorded. Also recorded was the type of unit from which each larva were collected. Control and fault boxes were taken from each shelf. This procedure was repeated over 3 *E. cautella* generations, although only 7 fault boxes were sampled following the final generation. The culturing medium was not renewed at any stage during the experiment. The total number of adults collected in the cage after the experiment was approximately 1000. Temperature (25±5°C) and relative humidity (55±10%) were only partially controlled while the lighting regime was 16L:8D with 'lights off' at 2100. All boxes were fumigated with methyl bromide prior to overwrapping, but their contents were not standardised. Fig. 6. shows an earlier trial of this experiment in progress.

Three-factor analysis of variance was undertaken to determine the influence of: (1) time of sample (following first, second or third *E. cautella* generation); (2) treatment (fault or control) and; (3) shelf (upper, middle or lower) on the number of *E. cautella* found within boxes. Variances were stabilized by transforming the data by 'log (x + 1)' where x was the number of *E. cautella* collected. Tukey's test was used to compare non-identical means (Zar, 1984).

To determine the distribution of larvae within a box, the frequency distribution of the number of larvae per unit (in boxes that contained >24 larvae) was analysed for its goodness of fit to mathematical models that have been proposed to describe the distribution of organisms in space (Southwood 1978). Frequency data was pooled in some cases to ensure 'expected' values were >3. Green's (1966) index of dispersion was calculated to describe the degree of contagion of the population. Green's index ranges from 0, representing random dispersion, to 1, representing a high degree of contagion.

Fig. 6. Experimental set up used to determine the influence of package integrity on infestation of chocolate-based consumables by *Ephestia cautella*.

(ii) ***Plodia interpunctella***

Twelve boxes of 250g Roses were placed into a 60 x 60 x 60cm insect-proof cage (described previously). Six boxes had a hole in the overwrap, and were designated 'fault' boxes, while the other six 'control' boxes had no visible (to the naked eye) ruptures or tears in the overwrap. All fault boxes had a small hole (<5mm) on one corner of the box. These holes occurred during the routine overwrapping of boxes during manufacture; none were made artificially. Two control and two fault boxes were placed onto each of the three shelves in the cage. Two boxes (~15cm apart) were placed on the section of shelf that ran along the back of the cage, while one box was placed on each of the two sections of shelf that ran partially along the sides of the cage. Fault and control boxes were placed alternately on each shelf. The boxes remained in the cage for 24h before 30 (15 male + 15 female) adult *P. interpunctella* were introduced. The adults, of unknown age, were taken from existing *P. interpunctella* cultures reared on a diet of kibbled wheat, glycerol and brewer's yeast (10:2:1 by parts (Bell, 1975)). Temperature (25±5°C) and relative humidity (55±10%) were only partially controlled while the lighting regime was 16L:8D with 'lights off' at 2100. All boxes were fumigated with methyl bromide prior to overwrapping, although the contents of the boxes were not standardised.

Three weeks after the introduction of the adults, all boxes were opened and the number of larvae found in each box was recorded. Also recorded were the number of chorion (egg casings) attached to each box. The overwrap was carefully removed from each box and examined for signs of larval penetration. Two-factor analysis of variance was undertaken to determine the influence of treatment (fault or control) and shelf (upper, middle or lower) on the number of larvae found within boxes. Variances were stabilized by transforming the data by 'log (x + 1)' where x was the number of larvae collected. Analysis of variance was also undertaken to determine the influence of treatment and shelf on the number of chorion found on each box. Data was again transformed by 'log (x + 1)' where x was the number of chorion.

(iii) Surveys of the integrity of assortment boxes following packaging

Two surveys were conducted to determine the proportion of assortment products that contained an imperfection in the overwrap at the time of manufacture at Claremont. The first was a sporadic survey undertaken by the author during 1994 and 1995 of newly packaged produce. For this, assortment boxes, all of which were geometrically cuboid, were randomly selected and examined individually for packaging faults (tears or ruptures in the overwrap) that were categorised in either of 5 ways:

I - fault on a vertical surface of a box

II - fault on a horizontal surface of a box

III - fault on a horizontal/vertical edge of a box

IV - fault on a vertical/vertical edge of a box

V - fault on a corner of a box

An additional category (VI) was used to classify boxes that had not been entirely covered by the overwrap due to the uneven application of the film. Occasionally boxes had more than one type of packaging fault. In such cases, boxes were placed into the category of the fault that was first detected during inspection.

A second survey was undertaken by Quality Assurance personnel at the Claremont factory. From August to November 1994, boxes sampled for routine quality testing were also examined for overwrapping faults. In this survey, only the presence or absence of an overwrapping fault was recorded. Boxes in both surveys were examined without the aid of magnification.

5.2.5 The protective qualities of two flexible polymer packaging films against invasion by stored-product insects

The ability of stored-product pests to penetrate two types of clear overwrap, polyvinyl chloride (PVC) and polypropylene (PP) were examined. The PVC film was a shrink-wrap, 25μm thick that was self-sealing when heat was applied. The PP film was 28μm thick and self-sealing, with one side acrylic and the other P.V.D.C. The PP film was biaxially oriented, but was not a shrink-wrap. All assortment varieties manufactured at Claremont and sold domestically are overwrapped with PVC except the 'After Dinner Mint' lines which are wrapped with cellophane. The PP film is used to overwrap an assortment variety that is exported to Asia.

Both newly hatched (<24h old) and wandering fifth instar *E. cautella* and *P. interpunctella* larvae were tested for their ability to penetrate both overwraps. Fifth instar larvae were collected directly from 4l culturing jars that containing ~500g of culturing media (kibbled wheat, glycerol and brewers yeast (10:2:1; Bell, 1975)). The newly hatched larvae were collected via the method described in 5.2.2. Adult *Tribolium confusum* (confused flour beetle) were also tested for their ability to penetrate each type of overwrap, and were collected directly from 4l culturing jars that contained 1kg of wholemeal flour. All cultures were maintained in a room in which the temperature (25±5°C) and relative humidity (55±10%) were only partially controlled, and the lighting regime was 16L:8D with 'lights off' at 2100.

E. cautella and *P. interpunctella* larvae, and *T. confusum* adults, were placed into heat-sealed PVC or PP pouches (after Cline, 1978). The pouches were constructed by folding a 6 x 4cm section of film in half (3 x 4cm) and then sealing two of the edges by applying heat. A single insect was then placed into each pouch before the final edge was sealed. The pouches were then placed into petrie dishes and incubated (25±1°C, 75% relative humidity, 16L:8D). No food was supplied to the insects during the trials. The pouches were examined daily (up to 5 days) for signs of penetration by the insect.

Two additional trials were undertaken with newly hatched *E. cautella* larvae. Firstly, 0.5g of the culturing medium was placed into PVC pouches, which were then sealed, and a single larva was placed onto the outside of the pouch. The pouches were then incubated and examined as before. Secondly, 0.5g of culturing media was again placed into PVC and PP pouches and then 10 larvae were placed onto the outside of the pouch and another 10 placed on the floor of the petrie dish. Again, the pouches were incubated and examined as before.

Insects were scored as having penetrated the overwrap only if a clear exit or entry hole was located. Occasionally, small larvae escaped the pouches through small gaps where the edges of the pouches had not sealed properly. These results were discarded. Newly hatched larvae that died before the first inspection (24h after containment) were not included in the results. Fifth instar larvae that pupated before the end of the trial period (5 days) were also excluded from the results.

5.3 RESULTS

5.3.1 Oviposition behaviour of *Ephestia cautella* and *Plodia interpunctella* in response to odours from chocolate-based consumables

(i) Cage experiment

A total of 255 eggs were laid on the boxes and trays during the experiment (Table 1). Chi-square analysis revealed that although the total number of eggs laid around treatment and control boxes was similar, significantly more eggs were attached to treatment boxes than were attached to the control boxes.

Table 1. Number of *Plodia interpunctella* eggs laid on fault (holes in overwrap) and control (no holes) boxes and on trays placed under the boxes. The chi-square value indicates the goodness of fit of the distribution of eggs between box and tray for fault boxes compared to control boxes. *** - P<0.001.

Treatment	No. eggs laid (%)		Total (%)	$\chi^2_{0.05(1)}$
	Box	Tray		
Fault	37 (27.4)	98 (72.6)	135 (100)	23.30***
Control	16 (13.3)	104 (86.7)	120 (100)	
Total	53 (20.8)	202 (79.2)	255 (100)	

Analysis of variance revealed that there was no significant difference between the number of eggs laid on or around fault or control boxes (Table 2). This result suggested that either: (1) *P. interpunctella* females lacked the capacity to discriminate between fault and control boxes; (2) females were unable to discriminate between the treatments due to an excessive quantity of stimulant (odour) in the cage; or (3) females did not discriminate between the treatments because both released attractive stimuli (odour). This final possibility is the most likely explanation for this result; it was found, during oviposition trials utilizing the chamber apparatus (see below), that odour escaped from apparently completely sealed boxes. Consequently, there was probably little to distinguish fault boxes from control boxes despite the overwrap of fault boxes being artificially punctured.

Table 2. Analysis of variance of the number of *Plodia interpunctella* eggs laid: (A) on or around each treatment; (B) on each shelf and; (C) on or around each box end. * - P<0.05, ** - P<0.01, ns - not significant.

Factor(s)	*df*	ms	F
A	1	0.2328	2.01ns
B	2	0.8698	7.52**
C	1	0.5558	4.81*
A x B	2	0.1234	1.07ns
A x C	1	0.1054	0.91ns
B x C	2	0.0949	0.82ns

There was, however, significantly more eggs laid on the top shelf of the cage than the middle and lower shelves (Table 2; Fig. 7). It is thought that this was the result of odour escaping from the boxes and accumulating near the roof of the cage, which, in turn, provided a greater stimulus for oviposition than the less concentrated atmosphere below. The oviposition trails undertaken with the chamber apparatus (see below) clearly indicated that the attractive components of the product odour do rise, and that, to a degree, oviposition response is positively correlated with the concentration of the odour. Also, general observations of phycitine moth behaviour indicated that, in the absence of food, adults had little apparent preference as to where in a cage they rested or oviposited, provided they were either on a vertical surface (e.g. the walls of the cage), or upside down on a horizontal surface (e.g. the roof of the cage or the underside of the shelving). Adults tended to avoid resting or ovipositing while upright on horizontal surfaces, particularly the floor of the cage (*pers. obs.*). Therefore, egg distribution was thought to be primarily dependent upon the presence of differential odour concentrations within the cage, and the effect of other factors (e.g. proximity to light source, temperature variability, or predator avoidance behaviour) was thought to be negligible.

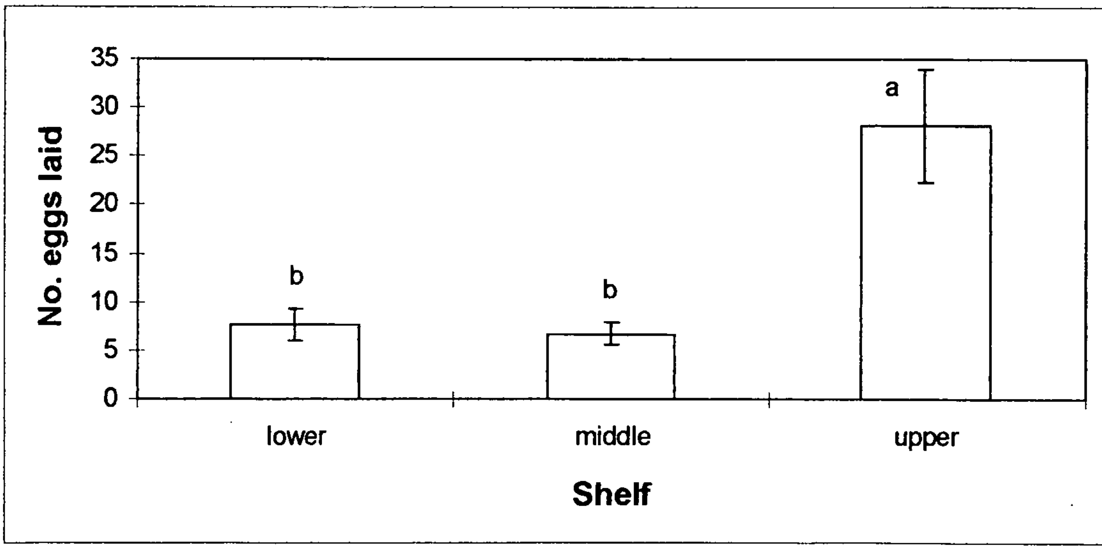


Fig. 7. Mean (±SE) number of *Plodia interpunctella* eggs laid on each shelf of the cage. The mean number of eggs laid on each shelf with the same letter was not significantly different at the 5% level of probability (Tukey Test).

Eggs were exclusively laid at the ends of both control or fault boxes (Fig. 8), with significantly more laid at the end of boxes that faced the rear of the cage (Table 2; Fig. 9). This suggests that, firstly, attractive odours escaped from the ends of not only fault boxes, where the overwrap was punctured, but also the control boxes, which had no such overwrap punctures.

Secondly, the finding that more eggs were deposited at the ends of boxes that faced the rear of the cage might indicate that either the odours escaping from the boxes were confined, and concentrated, in the area immediately below the shelving and against the back of the cage, providing increased stimulation for oviposition, or that these areas presented more suitable surfaces (horizontal and vertical) for oviposition than the more open area towards the front of the cage. It is possible that both of these factors operated together to achieve this result.

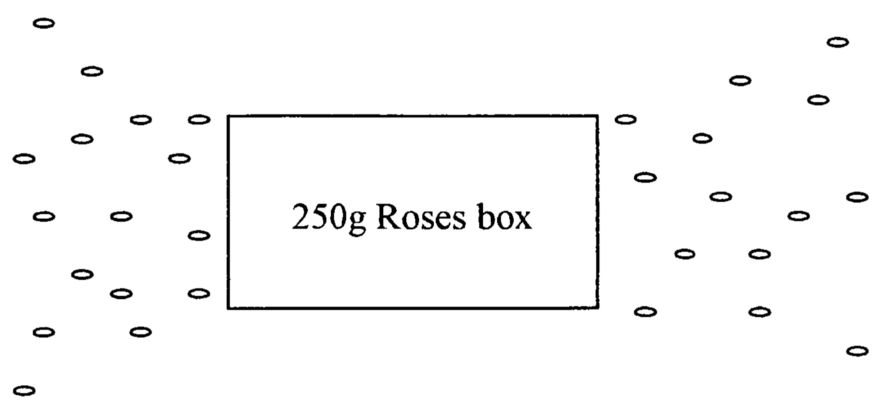


Fig. 8. Graphical representation of the distribution of *Plodia interpunctella* eggs laid around a box of 250g Roses.

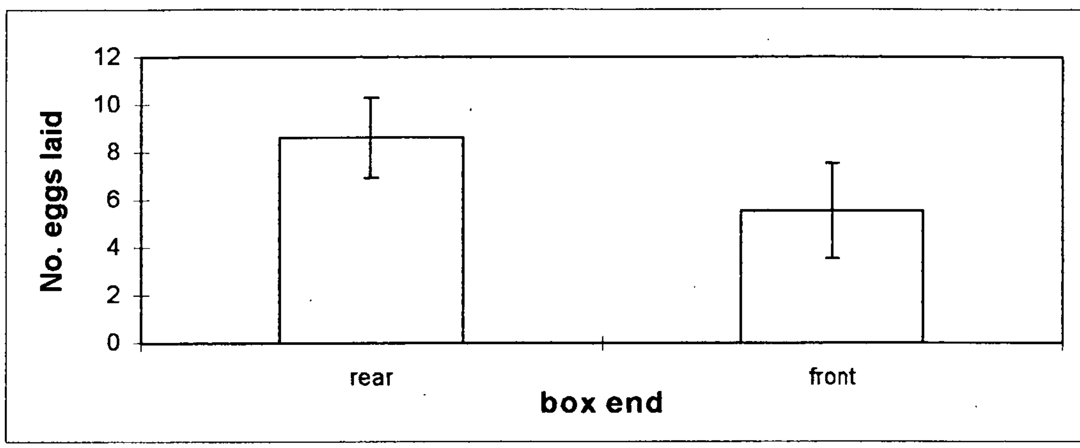


Fig. 9. Mean (±SE) number of *Plodia interpunctella* eggs laid at the ends of boxes facing either the front or rear of the cage.

The positioning of eggs attached directly onto the fault boxes was very interesting. Almost one third of the eggs were actually laid through the artificially made holes (designated as '0'cm from hole; Table 3). In all such cases, the sticky eggs were attached to the inner surface of the film. Fig. 10a (photograph taken from an earlier trial) shows six *P. interpunctella* eggs attached to the inner surface of the film around the edges of the hole. The gap between the lid and the side of the box can clearly be seen. All other eggs laid on the fault boxes were laid on the ends of the boxes, generally in wrinkles or creases in the film that were prevalent on the corners (>4cm from the hole). Fig. 10b, again from an earlier trial, shows two *P. interpunctella* eggs attached to the inner surface of the film around the edge of the hole, and nine eggs attached to the outer surface of a wrinkle in the film. Eggs were also attached to the ridges formed by the envelope-type folds at the ends of each box. The sides and top of the boxes had no such crevices and, for this reason, they were possibly less preferred as oviposition sites.

Table 3. Position of *Plodia interpunctella* eggs laid in relation to the mechanically made holes in fault boxes.

Distance from hole (cm)	No. eggs laid (%)
0	12 (32.4)
1	3 (8.1)
2	2 (5.4)
3	1 (2.7)
4	1 (2.7)
>4	18 (48.7)
Total	37 (100)

(ii) Chamber experiments

Females of both species laid, in total, significantly more eggs in response to the odours emanating from a box of Roses than they did in response to no odour, although the positioning of the eggs differed between the two species. Female *P. interpunctella* preferred to attached their sticky eggs to the mesh lid and base of the chamber (Fig. 11a). Significant more *P. interpunctella* eggs were laid on the base of the chamber directly over the outlet of the container housing the box of chocolates than over the outlet of the empty (control) container. More eggs were also attached to the mesh around the 'chocolate' outlet than the control outlet although the difference was not quite significant ($P = 0.052$). There was no significant difference in the number of eggs attached to either half of the lid of the chamber. This suggests that by the time the odour reached the lid, it may have diffused sufficiently to fail to elicit a clear oviposition preference. Very few eggs were collected from the tray or from within the containers.

By contrast, almost all of the non-sticky *E. cautella* eggs were laid through the mesh and collected either on the tray or in the collecting dishes placed below the outlets in each container (Fig. 11b). Significantly more eggs were laid on the half of

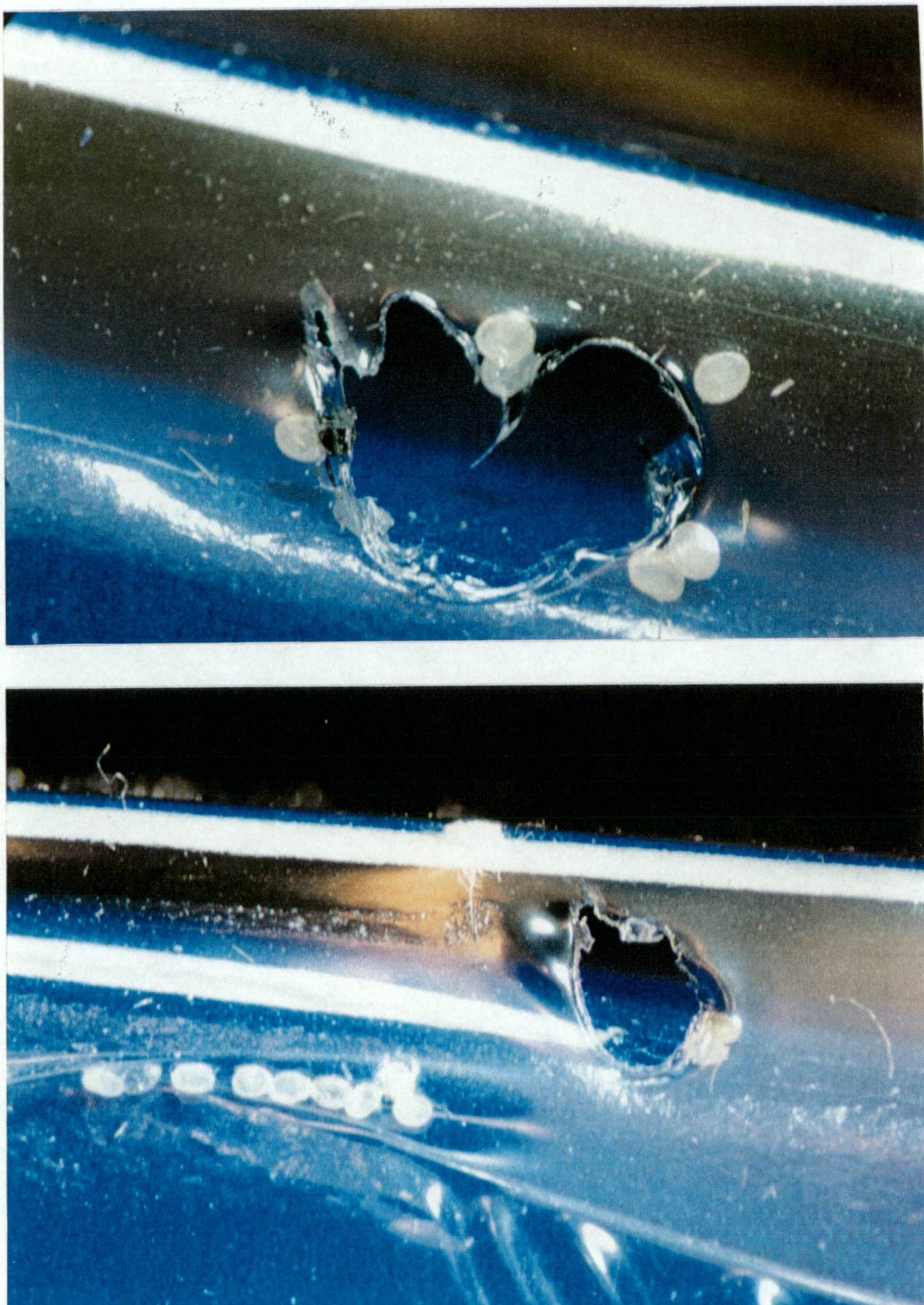


Fig. 10. Positioning of eggs by *Plodia interpunctella* females on assortment boxes whose overwrap had been artificially punctured: Top - eggs laid through the hole in the overwrap and attached to the inner surface of the film (x20); Bottom - eggs laid both through the hole in the overwrap and attached to the inner surface, and onto the exterior surface of the overwrap attached to creases in the film (x10).

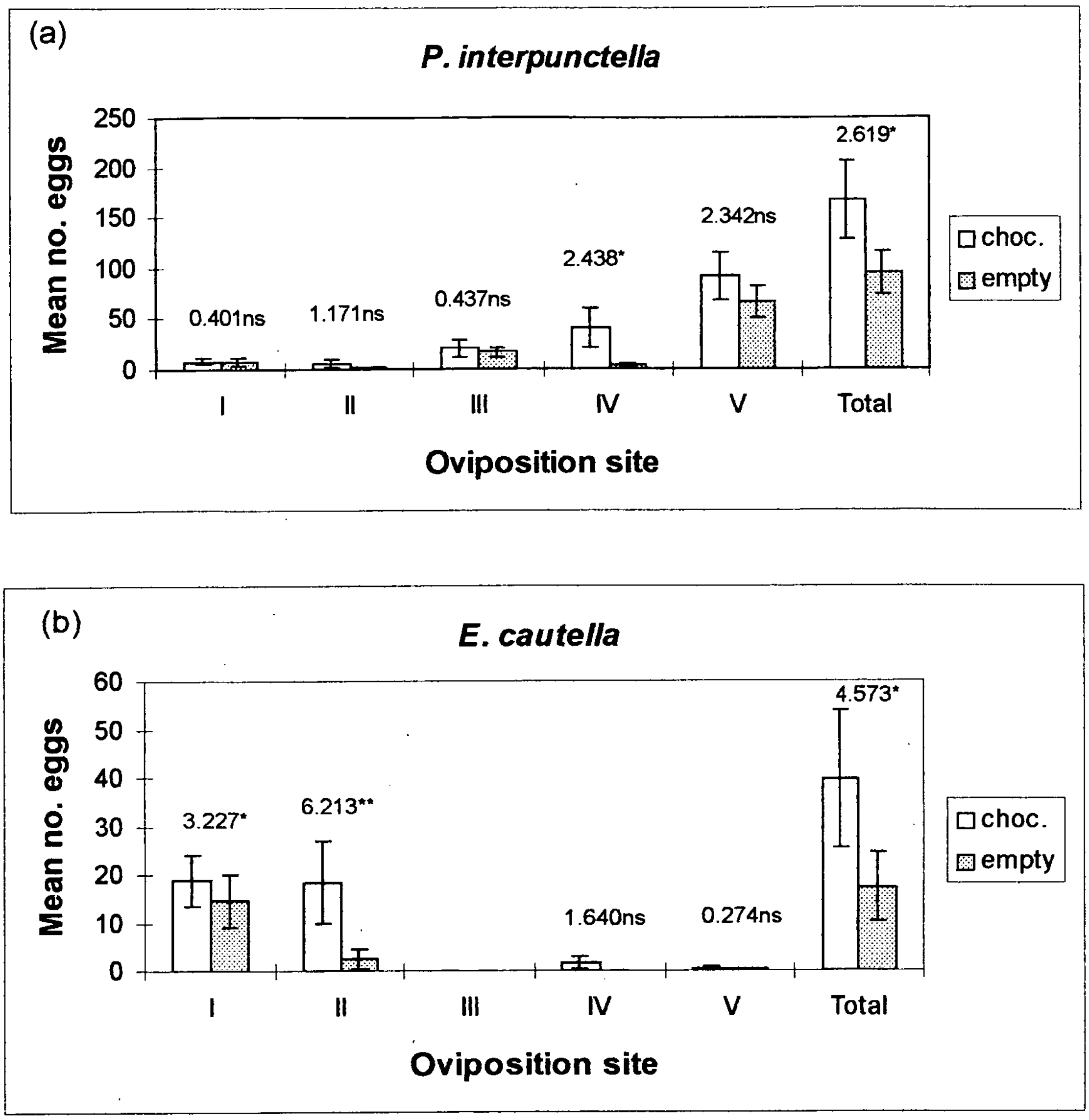


Fig. 11. Mean (±SE) number eggs laid by (a) *Plodia interpunctella* and (b) *Ephestia cautella* females in an oviposition chamber placed above two containers, one housed a box of chocolates (choc.) and the other acted as a control (empty). Oviposition sites were categorised in 5 ways: I - eggs laid on the tray covering each container; II - eggs deposited down the outlet tubes and collected within the containers; III - eggs attached to the (mesh) chamber lid; IV - eggs attached to the (mesh) base of the chamber directly over the outlet and; V - eggs attached to the (mesh) base of the chamber around over the outlet. The numerical values above the columns in each graph represent the $t_{0.05(df)}$ values calculated by paired-sample t-tests to determine the differences in the (log transformed) number of eggs laid at each oviposition site in response to each treatment (choc. and empty). * - $P<0.05$, ** - $P<0.01$, ns - not significant.

the tray that covered the container housing the chocolates than on the other half of the tray covering the empty control container. Also, significantly more eggs were also laid directly through the outlet tube into the container containing the chocolates than into the empty container. Very few eggs were attached to the basal mesh of the chamber, and none were found on the lid.

It was clear that females of both species were able to position a significant proportion of their eggs as close as possible to the source of the odour; 16% of all *P. interpunctella* eggs laid were attached to the base of the chamber directly over the outlet of the container housing the box of chocolates, and 33% of all *E. cautella* eggs laid were deposited directly over the outlet of the container that housed the chocolates so that they fell into the container.

In which of the two containers the box of chocolates was placed in did not significantly influence the number of eggs laid in either the experiments involving *P. interpunctella* ($t = 0.528$, $df = 14$, $P > 0.05$; Two-sample t-test) or *E. cautella* ($t = 0.400$, $df = 6$, $P > 0.05$; Two-sample t-test).

The experiment involving both intact and fault boxes of Roses revealed that, although eggs were distributed within the chamber in a similar pattern as above, female *P. interpunctella* failed to distinguish between the two treatments (Fig. 12). This agreed with the findings of the cage experiment. However, on this occasion, the escape of volatiles from the so-called intact boxes was positively identified as the reason why females did not discriminate between the treatments. When the container housing the intact box of Roses was opened at the completion of each replicate, a strong odour within the container was noted on each occasion. No such odour was ever noticed in the previous series of experiments when the control container was left empty. This confirmed that the presence of volatiles in the container housing the intact box was not somehow due to odours from the fault box filtering into this container, but was entirely due to odours escaping from the intact boxes.

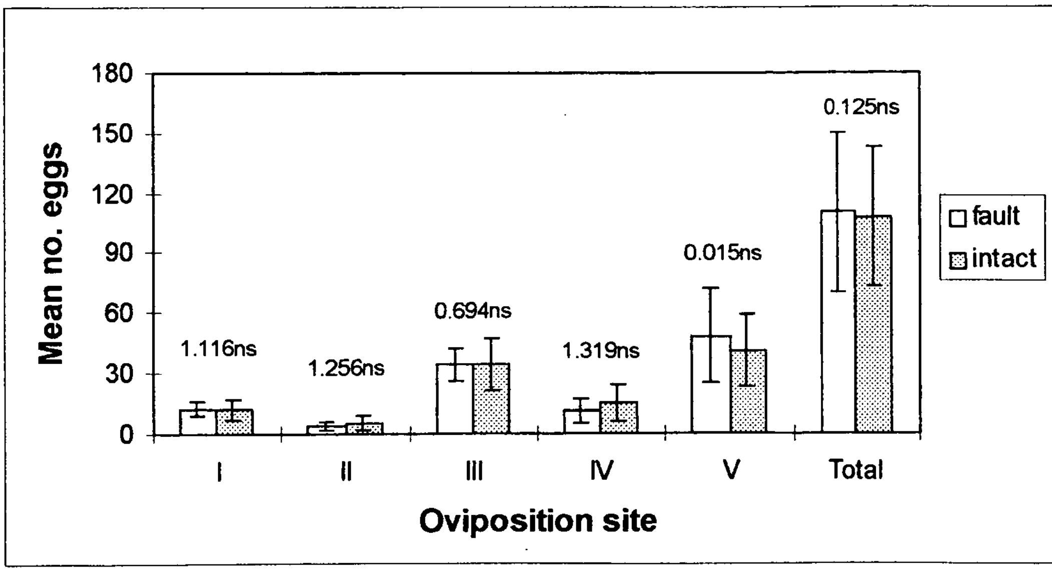


Fig. 12. Mean (±SE) number eggs laid by *Plodia interpunctella* females in an oviposition chamber placed above two containers, one housing a box of Roses with artificially made holes in the overwrap (fault) and the other housing a box of Roses with no obvious holes in the overwrap (intact). Oviposition sites were categorised in 5 ways: I - eggs laid on the tray covering each container; II - eggs deposited down the outlet tubes and collected within the containers; III - eggs attached to the (mesh) chamber lid; IV - eggs attached to the (mesh) base of the chamber directly over the outlet and; V - eggs attached to the (mesh) base of the chamber around over the outlet. The numerical values above the columns in each graph represent the $t_{0.05(df)}$ values calculated by paired-sample t-tests to determine the differences in the (log transformed) number of eggs laid at each oviposition site in response to each treatment (fault and intact); ns - not significant.

5.3.2 Orientation and movement of newly-hatched *Ephestia cautella* and *Plodia interpunctella* larvae in response to light and/or food odours

Newly hatched *E. cautella* larvae were found to be negatively-phototactic. Significantly more larvae moved away from the light source regardless of whether it was placed up- or downwind (Table 4). The response was generally quite rapid with the larvae taking approximately 13-14 minutes to move the required 20mm. The larvae did not usually move directly along the tube; but often circled the inside of the tube, stopping periodically and exhibiting “klinotaxis” (Wigglesworth, 1966). Significantly, only a small proportion of larvae failed to respond to the photo-stimulus within the allocated 30 minute trial period.

Table 4. Movement of newly hatched *Ephestia cautella* larvae in response to a light source placed either up- or downwind of the Y-tube testing apparatus. Chi-square analysis tested whether larvae were equally likely to move toward the light source as away from the it. * - $P<0.05$, ** - $P<0.01$. n - number of larvae tested.

Light position	n	Response				Response time (min) $\bar{x}$ (± SE)	
		Upwind	Downwind	$\chi^2_{0.05(1)}$	None	Upwind	Downwind
Upwind	8	0	7	7.00**	1	-	14.00 (± 3.14)
Downwind	13	9	2	4.45*	2	13.13 (± 2.24)	10.50 (± 0.71)

The response of larvae of the two species to odours produced by the two food sources was quite different (Table 5). *E. cautella* larvae generally failed to respond at all to roasted hazelnuts odours. Positioning larvae at the junction of the Y-tube, rather than 10mm from the junction, did not alter the response pattern of the larvae to roasted hazelnuts. *P. interpunctella* larvae, on the other hand, were highly responsive to roasted hazelnuts; only 4 larvae failed to move the required 20mm in the allotted time, and, of those larvae that moved upwind, significantly more moved toward the food than toward the empty vial. This clearly indicated that the *P. interpunctella* larvae were, firstly, able to recognize the roasted hazelnuts as a potential food source by their odour and, secondly, were then able to orientate and move toward the source of the odour. The response of *P. interpunctella* larvae to milk chocolate was not as

Table 5. Movement of newly emerged *Ephestia cautella* and *Plodia interpunctella* larvae in response to hazelnut or milk chocolate odours. Chi-square analysis was used to determine whether larvae that moved upwind were equally likely to move towards the control vial as toward the vial containing the test material; *** - P<0.001, ns - not significant.

Species	Test material	No. larvae	Response					Response time (min) $\bar{x}$ (± SE)		
			Upwind			Downwind	None	Upwind		Downwind
			Test	Control	$\chi^2_{0.05(1)}$			Test	Control	
E. cautella	Hazelnuts	20	2	0	-	2	16	17.50 (± 3.53)	-	12.50 (± 3.53)
	Hazelnuts[1]	20	2	0	-	2	16	17.50 (± 3.53)	-	10
	Milk chocolate	40	7	2	2.78ns	10	21	11.43 (± 2.61)	25 (± 7.07)	16.43 (± 2.99)
P. interpunctella	Hazelnuts	40	15	1	12.25***	20	4	17.67 (± 1.82)	10	14.50 (± 1.77)
	Milk chocolate	40	9	4	1.96ns	16	11	11.11 (± 1.82)	18.75 (± 4.73)	13.13 (± 1.98)

[1] - larvae positioned at the junction of the Y-tube.

evident, with a higher proportion of larvae failing to respond to the odour. Of the larvae that moved upwind, more than twice as many moved toward the food as moved toward the empty vial, although the difference was not statistically significant. *E. cautella* larvae were more responsive to milk chocolate odours than roasted hazelnut odours, although, again a considerable proportion of larvae failed to respond in the allocated time. Of the larvae that moved upwind, more than three times as many moved toward the food as moved toward the empty vial, although the difference was not statistically significant. It is likely that with additional replication, both species would show a statistically significant preference for milk chocolate over the empty vial.

The high proportion of larvae that moved downwind does not indicate that these larvae preferentially moved away from the food source, but rather, this result was an artefact of the method. The concentration of odour in the primary arm of the Y-tube, where larvae were usually initially positioned, was likely to have been uniform along the length of the tube, except at the junction where the primary arm branched. Consequently, due to this uniformity, larvae were equally as likely to initially move downwind as they were to move upwind. This is confirmed by the results which show that the number of larvae that moved upwind and downwind were almost equal in each set of trials. Only larvae that moved upwind to the junction of the Y-tube would have encountered variable concentrations of food odours, and hence, only these larvae had the opportunity to 'choose' their preferred alternative. Larvae that moved downwind from the starting point would not have received any indication, via a reduction in odour concentration, that they were moving away from food source.

There was a degree of variability in the response times of larvae to food odours, and response time was not thought to be a particularly good index of preference. However, some interesting results should still be noted. Firstly, both *E. cautella* and *P. interpunctella* larvae took less time, on average, to move toward the milk chocolate food source (approximately 11 minutes) than they did to move toward the roasted hazelnut food source (approximately 18 minutes). Secondly, both *E. cautella* and *P. interpunctella* larvae took less time to move downwind away from the roast hazelnut food source (approximately 12 and 14 minutes respectively) than they did to move toward the food source (approximately 18 minutes). By contrast, larvae of both species took longer to move downwind away from the milk chocolate food source (approximately 16 and 13 minutes respectively) than they did to move toward the food source (approximately 11 minutes). Thirdly, larvae of both species that moved toward the empty control vial generally took considerable time doing so, suggesting a degree of hesitancy.

The chemotactic response of larvae in relation to the length of time the test material was used was examined to determine whether the stimulus provided by the test material decreased over time. Test material (milk chocolate or roasted hazelnuts) was only used for a maximum of two hours, and most trials took place within the first hour (Fig. 13). In trials using milk chocolate, a higher proportion of larvae of both species failed to respond (i.e. move the required distance) during the second hour of testing than during the first hour. This suggests that the stimulus provided by milk chocolate was negatively correlated with the length of time the material was used. *P. interpunctella* larvae, on the other hand, responded in a similar way to roasted hazelnuts regardless of how long the test material had been used, suggesting that the stimulus from roasted hazelnuts did not decrease over the two hour testing period. [The results of *E. cautella* larvae tested with hazelnuts were not illustrated in Fig. 13 due to the consistent lack of response].

When *E. cautella* larvae were subjected to competing photo- and chemo-stimuli, it was clear that the phototactic response predominantly influenced behaviour, with the majority of larvae moving away from the light, and hence, away from the food source (Table 6). The larvae took, on average, slightly longer to move downwind (away from the odour source) than they did in the earlier trials when only the photo-stimulus was placed upwind (see Table 4), although the difference was not significant (Two-sample t-test: $t = 1.241$, $df = 13$, $P>0.05$).

Table 6. Movement of newly emerged *Ephestia cautella* larvae in response to a light source placed upwind of the Y-tube testing apparatus. Milk chocolate was placed in the 'test' vial and the 'control' vial was left empty.

No. larvae	Response				Response time (min) $\bar{x}$ (± SE)		
	Upwind		Downwind	None	Upwind		Downwind
	Test	Control			Test	Control	
11	1	1	8	1	16	17	16.75 (± 3.10)

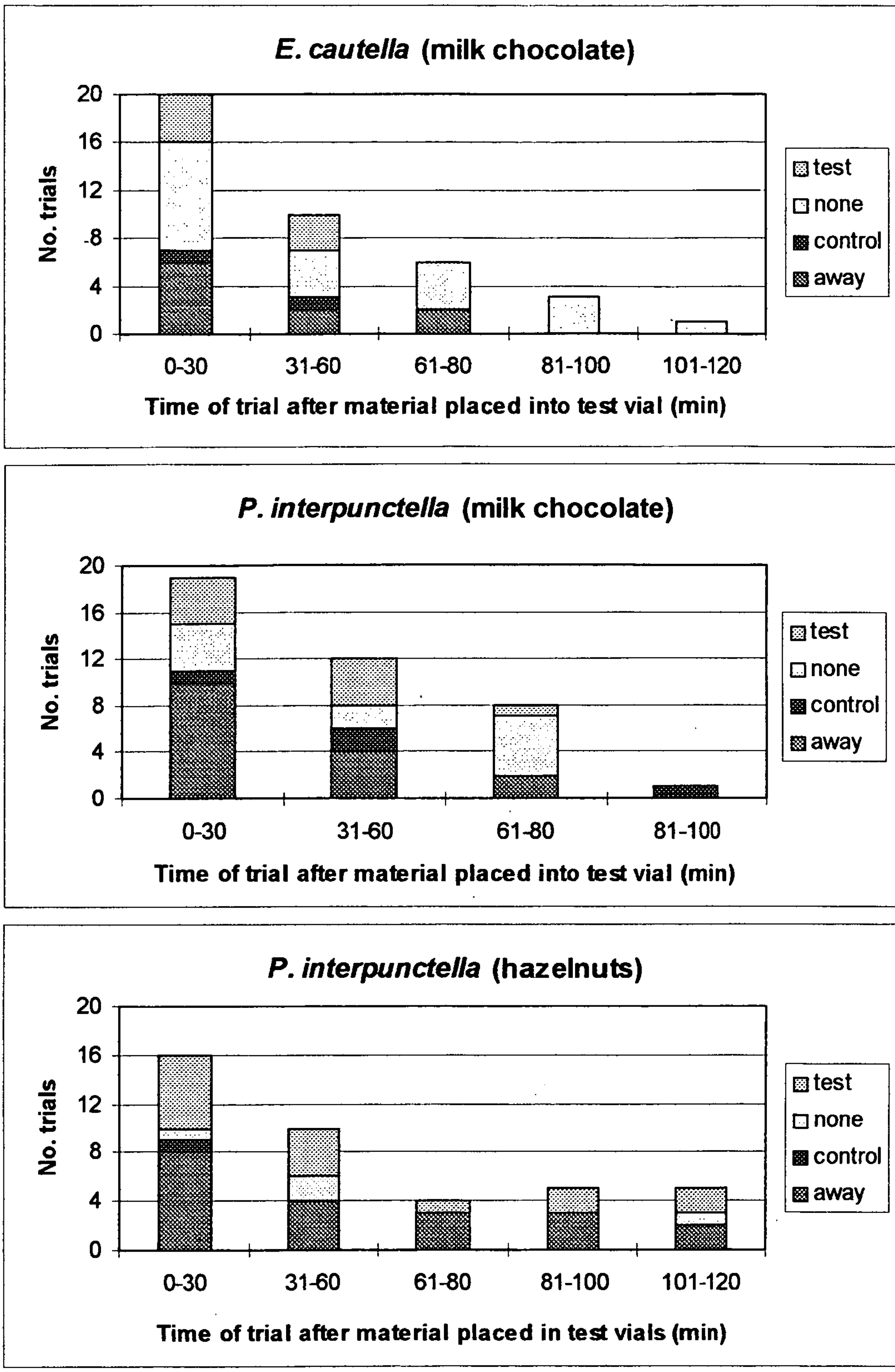


Fig. 13. The relationship between the response of newly hatched *Ephestia cautella* and *Plodia interpunctella* larvae to milk chocolate or hazelnut odours, and the length of time food material was used. Trials took place in a Y-tube and there were 4 possible outcomes: (1) larvae moved along the branching arm of the Y-tube attached to a vial containing the food material (test); (2) larvae failed to respond (none); (3) larvae moved along the branching arm of the Y-tube attached to an empty vial (control) or; (4) larvae moved along the primary tube away from the Y-tube junction (away).

5.3.3 Headspace analysis of assortment units, hazelnuts and milk chocolate

The two most abundant compounds identified in the headspace of Roses units were acetone and acetic acid (Table 7; Fig. 14) Various other volatiles were identified including two pyrazine compounds. The 2-propanol compound identified in the headspace may have been a taint from the aluminium foil wrappers removed from the Roses units immediately prior to testing. Analysis undertaken by the Queensland DPI found 2-propanol in the headspace of aluminium foil but not in the headspace above milk chocolate (data not shown).

The most prominent spike in the roasted hazelnut chromatograph (Fig. 15) was most likely 2,2,4,6,6, pentamethyl-heptane (Table 7). All compounds identified after the hexanal spike were hydrocarbons, although not all were identified individually due to time restrictions on the analysis. Other compounds found in abundance in the headspace of roasted hazelnuts were pentane, methanol, ethanol and hexanal. A number of common compounds were found in the headspace of both roasted hazelnuts and Roses units; these included methanol, ethanol, toluene and hexanal.

The most abundant compounds found in the headspace of milk chocolate (Table 8) were methanol, acetone, 2-methyl-propanal and 2-methyl-butanal. Not surprising a number of common compounds were identified in the headspace of milk chocolate and Roses units; these included methanol, ethanol, ethyl acetate, hexanal and benzaldehyde. Compounds that were common to both milk chocolate and hazelnuts were methanol, ethanol, acetone, heptane, methyl-cyclohexane and hexanal. All three materials analysed only had methanol, ethanol and hexanal as common constituents of their headspace.

Table 7. Volatile compounds identified in the headspace of Roses units and roasted hazelnuts. The peak numbers correspond to the peaks shown in the chromatographs for Roses units (Fig. 14) and roasted hazelnuts (Fig. 15).

Peak	Compound*	
	Roses units	Roasted hazelnuts
1	methanol[a]	methanol[a]
2	ethanol[a]	ethanol[a]
3	2-propanol[a]	acetone[a]
4	propanol[b]	pentane[a]
5	n-butanol[a]	isobutanal[a]
6	acetic acid[a]	3-methyl-butanal[a]
7	toluene[a]	2-methyl-butanal[a]
8	2-hexanol[b]	n-pentanal[a]
9	hexanal[a]	n-heptane[a]
10	ethyl-butanoate[a]	methylcyclohexane[a]
11	2,3-butane-diol[b]	isooctane[a]
12	butyl acetate[a]	toluene[a]
13	ethyl-2-methyl butyrate[a]	1-pentanal[a]
14	3-methyl-butyl acetate[a]	3-ethyl-pentane[b]
15	benzaldehyde[a]	hexanal[a]
16	trimethylpyrazine[a]	2,2,4,6,6-pentamethyl-heptane[b]
17	tetramethylpyrazine[a]	-

* ID code: a - identification confirmed; b - most likely but unconfirmed

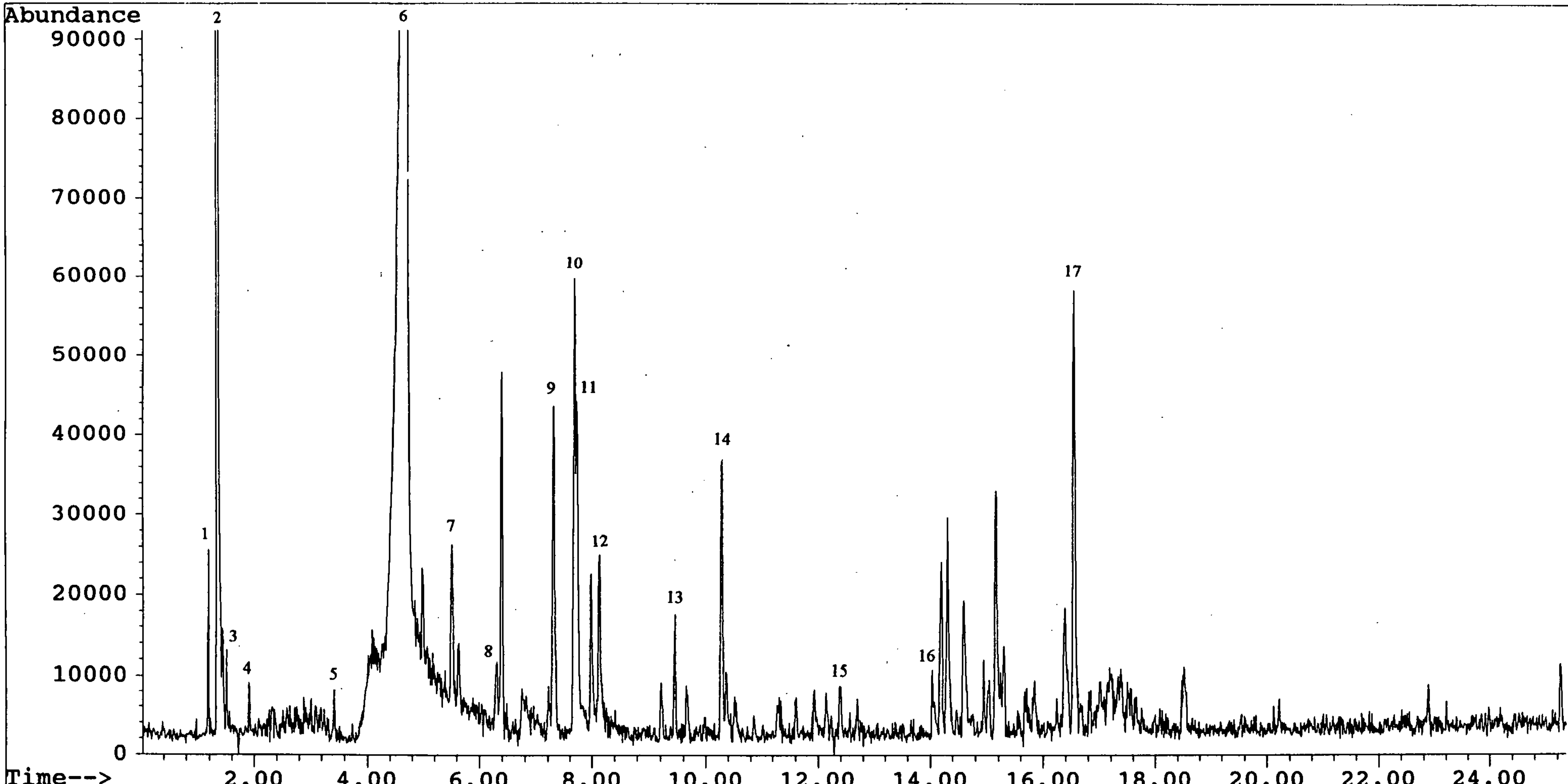


Fig. 14. Chromatograph of the compounds found in the headspace of Roses units. Only peaks that could be identified with a reasonable degree of certainty are numbered (see Table 7 for compound identification).

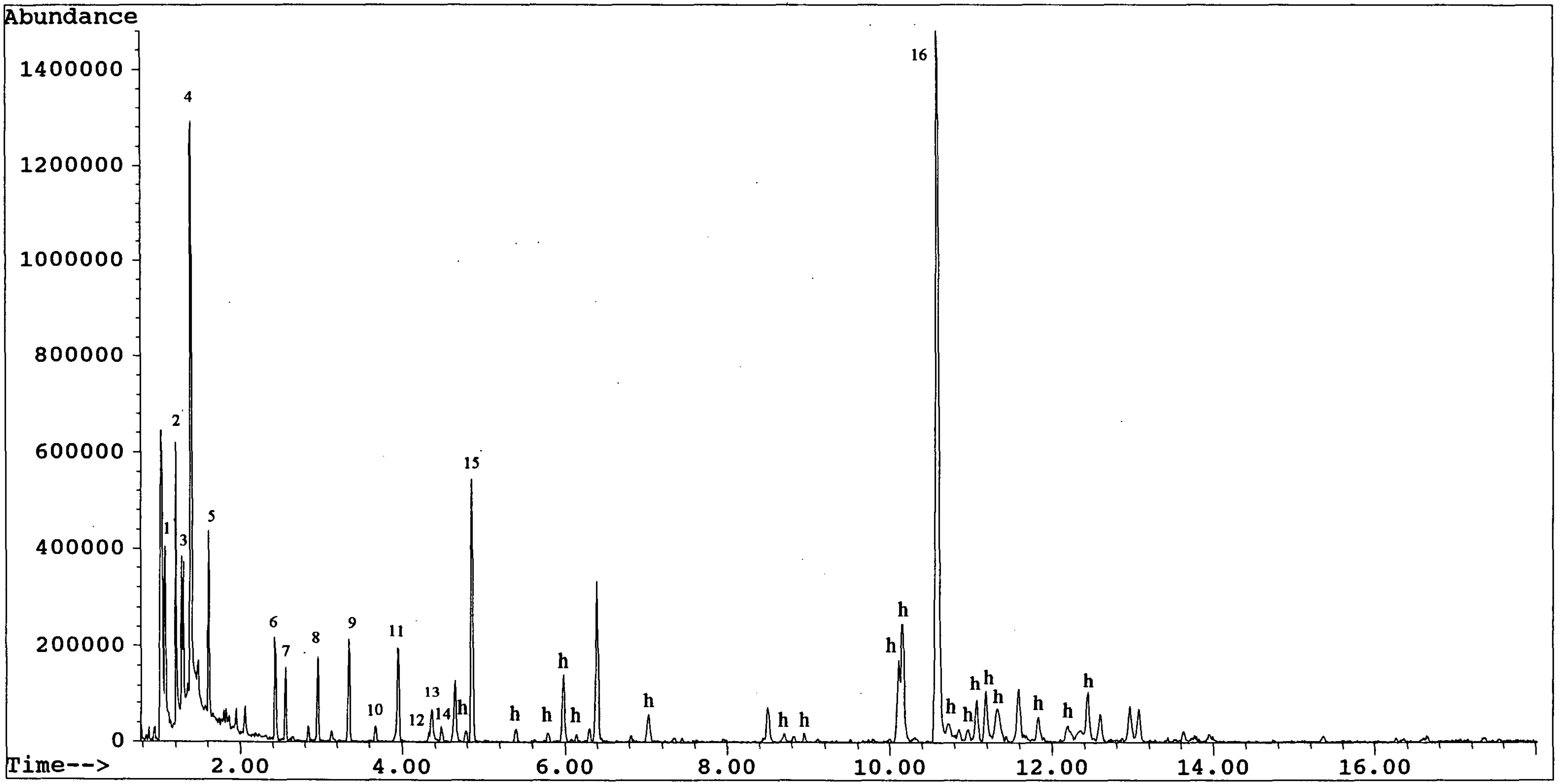


Fig. 15. Chromatograph of the compounds found in the headspace of roasted hazelnuts. Only peaks that could be identified with a reasonable degree of certainty are numbered (see Table 7 for compound identification). h - hydrocarbon compound.

Table 8. Volatile compounds, and their relative abundances, identified in the headspace of milk chocolate. Results from analysis undertaken by the Department of Primary Industries (Queensland) on behalf of Cadbury Schweppes.

Compound	ID code*	Abundance (arbitrary units)
methanol	A	5662
ethanol	A	981
acetone	A	3494
pentane	A	359
dichloromethane	A	145
2-methyl-propanal	A	4810
2-methyl-propane	B	862
ethyl acetate	B	17
2-butanone	A	507
2-butanol	A	57
hexane	A	1297
tetrahydro-furan	B	46
methyl-cyclopentane	B	238
3-methyl-butanal	A	5052
benzene	A	49
cyclohexane	A	18
2-pentanone	A	1424
pentanal	A	1970
heptane	A	197
methyl-cyclohexane	A	59
1-methoxy-2-propanol	B	73
methyl-benzene	A	172
hexanal	A	312
octane	A	122
3-methyl-2-butanol, acetate	B	47
2-pentanol, acetate	B	117
1,4-dimethyl benzene	A	75
2-heptanone	A	703
heptanal	A	64
1,2-dimethyl benzene	A	22
Nonane	A	25
4,5-dimethyl-1-hexane	B	22
alpha-pinene	A	28
benzaldehyde	A	267
1-ethyl-3-methyl benzene	B	24
dimethyl-trisulphide	A	20
2,3,6-trimethyl heptane	B	54
1-ethyl-2-methyl-benzene	B	28
beta-pinene	A	27
1,2,3-trimethyl-benzene	B	65
2,2,3,4-tetramethyl-pentane	B	78
2-decanal	B	18
limonene	A	38
2,2,5,5-tetramethyl-hexane	B	31
3-methyl-tridecane	B	21
2,2-dimethyl-3-pentanol	B	23

* A - Identification confirmed, B - Most likely but unconfirmed

5.3.4 The influence of package integrity on the infestation of chocolate-based consumables by *Ephestia cautella* and *Plodia interpunctella*

(i) *Ephestia cautella*

Package integrity clearly influenced not only the likelihood of the chocolate boxes being contaminated by *E. cautella*, but also the degree of contamination (Table 9). Fault boxes were twice as likely to be invaded by *E. cautella* larvae than control boxes, and the degree of infestation was ~22 times greater. It was also evident that *E. cautella* could complete development within the boxes with a number of adults recovered, particularly in the final sample. The greatest number of *E. cautella* collected from a single box was 428 (425 larvae + 1 pupa + 2 adults). The high ratio of larvae to adults might suggest that the contents of the boxes provided a relatively poor food source for developing larvae thereby delaying pupation (Johnson, 1995).

Table 9. Number of *Ephestia cautella* collected from boxes of chocolates with a ruptured overwrap ('fault' boxes) compared to the number of *E. cautella* collected from boxes with no visible ruptures ('control' boxes) after exposure to 1-3 generations of the moth.

Exposure (generations)	Treatment	Boxes sampled	Boxes invaded	No. *Ephestia cautella* collected: Larvae	Pupae	Adults	Total
1	Fault	8	6	53	0	0	53
	Control	8	4	5	0	0	5
2	Fault	8	7	236	0	1	237
	Control	8	2	14	0	0	14
3	Fault	8	7	1019	15	26	1060
	Control	7	4	39	1	2	42
Total	Fault	24	20	1308	15	27	1350
	Control	23	10	58	1	2	61

Analysis of variance confirmed that significantly more *E. cautella* invaded fault boxes, and that the degree of infestation increased the longer boxes were exposed to *E. cautella* (Table 10). The shelf on which boxes were placed did not influence the degree of infestation, and the interactions between the three factors were also not significantly different.

Table 10. Analysis of variance of the influence of exposure time (A), treatment (B) and shelf (C) on the number of *Ephestia cautella* collected from chocolate boxes. * - P<0.05, ** - P<0.01, ns - not significant.

Factor(s)	*df*	ms	F
A	2	1.4407	11.99*
B	1	6.3295	52.66**
C	2	0.1657	1.38ns
A x B	2	0.1737	1.45ns
A x C	4	0.0467	0.39ns
B x C	2	0.0727	0.60ns

The utilization of resources (units) within a box was dependent upon larval density. As the density of larvae within a box increased, the proportion of units utilized by the larvae increased in a logarithmic manner (Fig. 16). Consequently, the larval density per unit increased at only a low, linear rate as the total number of larvae per box increased (Fig. 17).

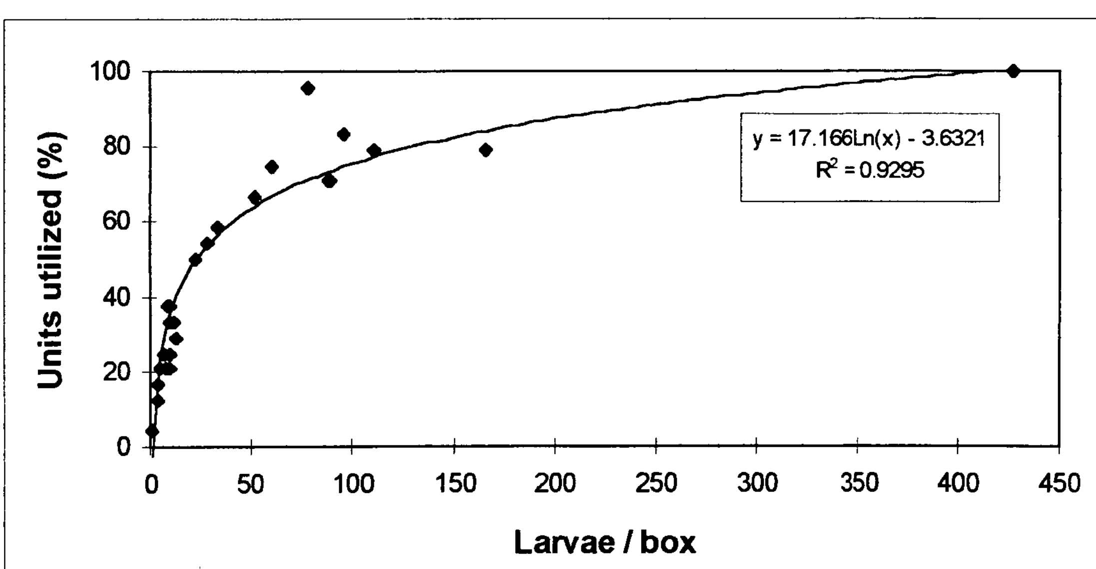


Fig. 16. Proportion of units utilized by *Ephestia cautella* larvae at increasing larval densities per box.

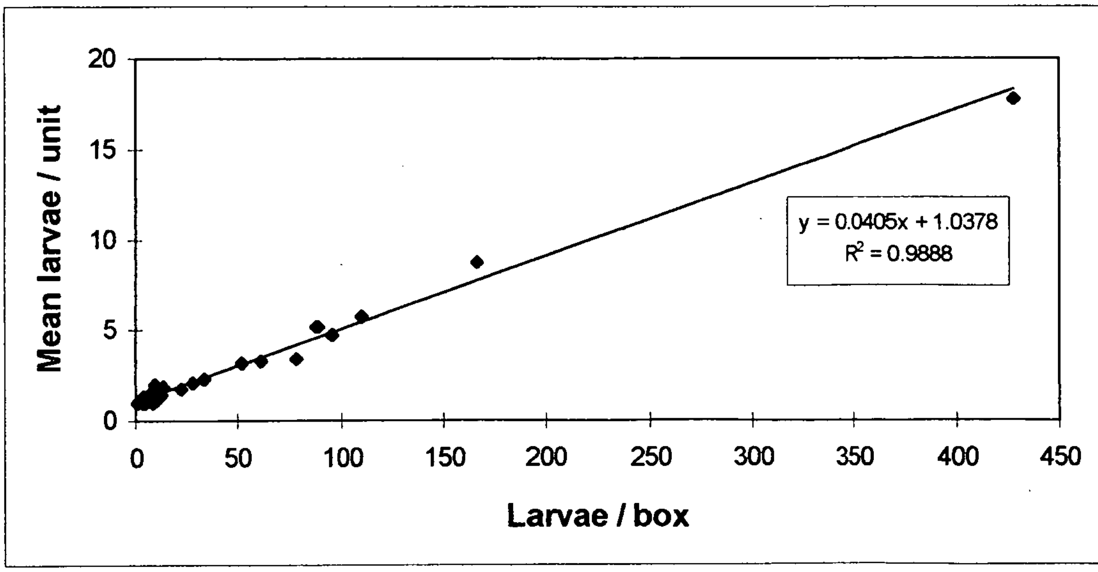


Fig. 17. Mean *Ephestia cautella* larval density per unit in response to increasing total larval density per box.

Although larvae were able to limit overcrowding by utilizing additional units, they were not distributed uniformly within boxes. In the 11 boxes that contained more than 24 larvae, the larvae in all except one were found to be distributed in a clumped pattern (Table 11). However, Green's index of dispersion revealed that the degree of clumping was very low in all cases indicating only a very loose aggregation of larvae within boxes.

Table 11. The mean, variance and goodness of fit to a negative binomial distribution of the number of *Ephestia cautella* larvae per unit in boxes containing >24 larvae. Green's index (GI) indicates the degree of dispersion.

Box	$\bar{x}$	s^2	χ^2	GI
1	2.154	6.141	7.284ns	0.069
2	2.357	4.401	11.744ns	0.027
3	3.250	10.867	6.071ns	0.046
4	3.389	9.193	6.195ns	0.029
5	3.391	5.067	5.664ns	0.006
6	4.800	16.484	2.533ns	0.026
7	5.176	16.279	8.373ns	0.025
8	5.235	38.566	7.700ns	0.072
9	5.789	26.953	4.217ns	0.034
10	8.737	30.538	13.895*	0.015
11	17.120	155.277	9.388ns	0.019

Unfortunately, larval preference for particular units within a box could not be determined because the contents of the boxes were not standardised before the experiment, so the mix of units between boxes varied. Also, the units that were free of larvae were not recorded, so a proportionate rate of infestation (no. larvae / no. units) could not be determined. However, what could be ascertained was that larvae were found feeding on all of the twelve types of units found within the boxes (Table 12). The low number of 'hazelnut whirl' units found to contain larvae did not indicate non-preference; due to poor mixing, this unit only occasionally occurred in boxes.

Table 12. The type and number of units in '250g Roses' boxes on which *Ephestia cautella* larvae were collected.

Unit type	No. units	No. larvae
Caramello delux	35	213
Cherry ripe square	27	138
Dairy milk whirl	16	54
Fruity fudge	34	166
Hazelnut whirl	7	36
Nut caramel	16	40
Peppermint cream	27	108
Raspberry sundae	21	124
Royal fudge	33	132
Strawberry cream	29	156
Turkish delight	15	81
Vanilla caramel	33	101

(ii) *Plodia interpunctella*

An equal number of fault and control boxes were invaded by *P. interpunctella* larvae, and the number of larvae collected from the each of the two treatments was almost identical (Table 13).

Table 13. Number of *Plodia interpunctella* larvae collected from boxes of chocolates with a ruptured overwrap ('fault' boxes) compared to the number of larvae collected from boxes with no visible ruptures ('control' boxes).

Treatment	Boxes sampled	Boxes invaded	No. larvae
Fault	6	4	13
Control	6	4	12
Total	12	8	25

As expected, analysis of the data revealed that there was no significant difference in the number of larvae found in each type of treatment box (Table 14). The shelf on which the boxes were placed on did not significantly influence the number of larvae found, and the interaction between treatment and shelf was also not significant.

Table 14. Analysis of variance of the influence of treatment (A) and shelf (B) on the number of *Plodia interpunctella* larvae collected from chocolate boxes. ns - not significant.

Factor(s)	*df*	ms	F
A	1	0.0002	0.002ns
B	2	0.1589	1.313ns
A x B	2	0.0919	0.760ns

The overwrap of each box was examined for evidence of larval penetration. Again, results were the same for the two treatments; three boxes from each treatment had penetrations in the overwrap and, in two of these, larvae were found on the chocolates inside, while no larvae were collected from the other box (Table 15). These results show that, firstly, the PVC overwrap was a poor physical barrier against newly hatched *P. interpunctella* larvae and, secondly, although larvae might penetrate the overwrap, they do not always then proceed to the contents of the box.

Table 15. The number of 'fault' (pre-existing holes in overwrap) and 'control' (no pre-existing holes in overwrap) boxes of chocolates penetrated by newly hatched *Plodia interpunctella* larvae, and the number of boxes subsequently found to contain larvae.

	Treatment				Total
	Fault		Control		
	Overwrap penetrated	Overwrap not penetrated	Overwrap penetrated	Overwrap not penetrated	
Larvae on contents	2	2	2	2	8
Larvae not on contents	1	1	1	1	4
Total	3	3	3	3	12

Larvae were also collected from fault boxes whose overwrap had not been penetrated (Table 15), indicating that *P. interpunctella* larvae utilized existing holes in the overwrap to invade boxes as well as entering by chewing through the overwrap. Larvae were also collected from control boxes whose overwrap had not been penetrated. This suggested that larvae were able to invade boxes through holes or gaps in the overwrap that were difficult to detect, even with the aid of magnification.

A total of 172 chorion were found attached to the boxes. All were attached to the external surface of the overwrap, and they were generally located on the vertical faces of the boxes in crevices or wrinkles in the overwrap. Analysis revealed that neither the treatment (fault or control) nor the shelf (upper, middle or lower) on which boxes were placed significantly influenced the number of chorion found on boxes (Table 16). The interaction between treatment and shelf was also not significant. The presence of chorion is not a meaningful indication of oviposition preference because these eggs probably only represent a fraction of the total eggs laid, and, also, newly hatched larvae occasionally eat their, or other's, egg casings, particularly after an unsuccessful period of searching for food (*pers. obs.*).

Table 16. Analysis of variance of the influence of treatment (A) and shelf (B) on the number of *Plodia interpunctella* egg casings collected from chocolate boxes. ns - not significant.

Factor(s)	*df*	ms	F
A	1	0.0716	0.252ns
B	2	0.3115	1.098ns
A x B	2	0.1915	0.675ns

There was no relationship between the number of chorions found on a box and the number of larvae subsequently found within the box (Fig. 18). This suggested that despite females being able to attach their eggs directly onto the boxes, and often very close to entry points (i.e. holes in the overwrap), only a small proportion of larvae subsequently entered the boxes and located the food. Assuming that the number of chorion found on the boxes represented only a small fraction of the total number of eggs laid, and that, in fact, each females laid approximately 200 eggs within the cage [the lower end of the range of *P. interpunctella* fecundity stated in Hill (1990)] and eggs hatch was 100%, then the probability of a newly emerged *P. interpunctella* larva locating the food source was:

= the number of larvae collected within the boxes / the estimated total number of larvae in the cage

= 25 / (15 x 200)

= 0.0083

This figure represents a larval infestation success rate of only 1 in 120. Clearly, the majority of larvae failed to locate the contents of the boxes despite often being positioned to advantage by adult females, their ability to chew through the overwrap, and the presence of existing entry points in the overwrap of 50 % of the boxes.

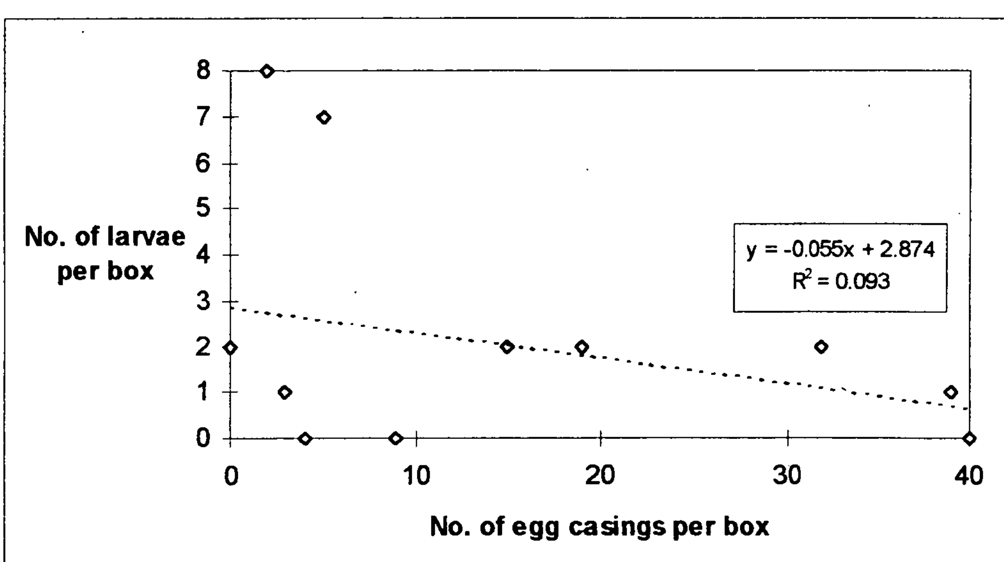


Fig 18. The relationship between the number of *Plodia interpunctella* chorion (egg casings) found on boxes of chocolates, and the number of larvae subsequently found within the boxes.

(iii) Surveys of the integrity of assortment boxes following packaging

The results from both packaging surveys clearly indicated that the majority of assortment boxes leave the factory with the integrity of the overwrap already compromised; 64% of the boxes examined by the author (Tables 17), and 85% of boxes inspected by Quality Assurance personnel (Table 18) contained overwrapping faults.

In the survey undertaken by the author, every batch of assortments sampled contained at least some boxes with faulty overwrapping. The sequential sampling of the '250g Roses' product showed that the degree, and also the type, of packaging faults varied. The most common type of packaging fault encountered was a tear in the overwrap on one (or more) of the corners of the boxes. This type of fault was consistent through all of the lines that were sampled. Most faults in the overwrap were generally <5mm, although faults occurring due to the uneven application of the overwrap (category VI faults) were sometimes >5mm.

Table 17. Survey undertaken by the author to assess the proportion of assortment products containing an overwrapping fault at the time of manufacture. Faults were categorised in six ways: I - fault on a vertical surface of a box; II - fault on a horizontal surface of a box; III - fault on a horizontal/vertical edge of a box; IV - fault on a vertical/vertical edge of a box; V - fault on a corner of a box and; VI - incomplete covering of a box by the overwrap. n - total number of boxes sampled.

Product	Date sampled	n	Fault type						Total faults (%)
			I	II	III	IV	V	VI	
250g Cabaret	29/1/94	84	1	3	8	3	17	26	58 (69)
250g Milk Tray	20/1/95	24	0	0	0	5	18	1	24 (100)
250g Roses	12/1/94	156	4	0	2	1	71	12	90 (58)
	10/8/94	47	0	0	5	12	8	1	26 (55)
	15/11/94	48	0	0	0	0	3	3	6 (13)
	21/1/95	24	0	14	0	0	8	1	23 (96)
	12/10/95	24	4	0	3	0	16	1	24 (100)
	14/10/95	24	0	0	1	2	11	2	16 (67)
500g Milk Tray	22/1/94	45	1	2	2	3	19	13	40 (89)
Total		476	10	19	21	26	171	60	307 (64)

A wider variety of assortment products were inspected by Quality Assurance personnel (Table 9). In all, except one, a high degree of packaging faults was found to occur. This shows that the compromising of package integrity at the time of manufacture was not limited to a few lines. In many cases, every box in a single sample contained an overwrapping fault. Again, according to Quality Assurance personnel, most of the faults were <5mm.

Table 18. Survey undertaken by Quality Assurance personnel to assess the proportion of assortment products containing an overwrapping fault at the time of manufacture. n - total number of boxes sampled.

Product	Date sampled	n	Total faults (%)
250g Roses	9/8/94	8	7 (88)
250g Roses	10/894	8	6 (75)
250g Milk Tray	11/8/94	8	7 (88)
250g Milk Tray	11/8/94	5	5 (100)
250g Milk Tray	12/8/94	8	6 (75)
250g Milk Tray	12/8/94	8	7 (88)
250g Milk Tray	15/894	6	4 (67)
250g Milk Tray	15/894	6	2 (33)
250g Milk Tray	16/8/94	6	4 (67)
250g Milk Tray	16/8/94	6	4 (67)
250g Milk Tray	17/8/94	7	5 (71)
250g Milk Tray	17/8/94	7	6 (86)
250g Milk Tray	18/8/94	6	5 (83)
250g Roses	22/8/94	6	5 (83)
250g Roses	23/8/94	6	5 (83)
750g Milk Tray	19/9/94	4	4 (100)
Milk Tray	20/9/94	6	6 (100)
Milk Tray	21/9/94	6	5 (83)
Milk Tray	22/9/94	6	4 (67)
250g Hazelnut Whirls	22/9/94	6	4 (67)
Milk Favourites	23/9/94	6	6 (100)
250g Roses	26/9/94	6	6 (100)
250g Roses	27/9/94	6	6 (100)
250g Roses	28/9/94	6	6 (100)
200g Liqueur Cherries	28/9/94	6	0 (0)
500g Milk Tray	10/10/94	6	6 (100)
250g Hazelnut Whirls	11/10/94	6	6 (100)
250g Milk Tray	12/10/94	6	6 (100)
250g Hazelnut Whirls	13/10/94	6	6 (100)
250g Milk Favourites	13/10/94	6	6 (100)
250g Milk Tray	17/10/94	6	6 (100)
500g Roses	18/10/94	6	5 (83)
500g Milk Tray	19/10/94	5	5 (100)
500g Milk Tray	19/10/94	5	5 (100)
250g Roses	24/10/94	5	4 (80)
250g Roses	24/10/94	5	5 (100)
300g Roses	26/10/94	5	4 (80)
300g Roses	26/10/94	5	3 (60)
200g Liqueur Cherries	27/10/94	5	2 (40)
250g Roses	31/10/94	5	5 (100)
250g Roses	2/11/94	4	4 (100)
250g Roses	3/11/94	5	5 (100)
250g Milk Tray	4/11/94	4	4 (100)
250g Milk Tray	7/11/94	6	6 (100)
250g Milk Tray	7/11/94	6	6 (100)
500g Milk Tray	8/11/94	6	6 (100)
500g Milk Tray	8/11/94	6	6 (100)
Total		277	235 (85)

5.3.5 The protective qualities of two flexible polymer packaging films against invasion by stored-product pests

Of the two types of overwrap materials tested, the polypropylene (PP) film was resistant to penetration by all three stored-product pests tested, while the polyvinyl chloride (PVC) was only resistant to newly hatched *E. cautella* (Table 19). Placing newly hatched *E. cautella* larvae on the outside of the pouch and increasing the larval density also failed to result in the penetration of either film by newly hatched *E. cautella*.

Table 19. The number of newly hatched, first instar larvae and fifth instar larvae that penetrated pouches made from polyvinyl chloride (PVC) or polypropylene (PP). n - number of larvae tested.

Overwrap	Species	Larval instar	n	No. penetrated
PVC	*E. cautella*	first	14	0
			10†	0
			20‡	0
		fifth	16	11
	P. interpunctella	first	8	2
		fifth	19	12
	T. confusum	-	15	1
PP	*E. cautella*	first	16	0
			60‡	0
		fifth	8	0
	P. interpunctella	first	15	0
		fifth	10	0
	T. confusum	-	15	0

† One larva placed on the outside of a pouch containing 0.5g of food.

‡ 20 larvae placed on and around a pouch containing 0.5g of food.

Larvae penetrated the PVC by making a circular exit hole on one of the edges, corners, or the upper surface (facing petrie dish lid) of the pouch. Fifth instar larvae occasionally also 'sheared' along an edge of the pouches. Exit holes of ~1mm were made by both large and small larvae and were usually characterised by excess frass

Fig. 19. Fifth instar *Plodia interpunctella* larval exit hole from a polyvinyl chloride (PVC) film pouch (x30).

and webbing, and fragmented pieces of film around the hole (Fig. 19). The adult *T. confusum* that penetrated the PVC also made an exit hole of ~1mm on the edge of the pouch.

Fifth instar larvae of both species generally penetrated the overwrap within the first 3 days of confinement, with little penetration occurring on the fourth or fifth days (Fig. 20). All fifth instar *E. cautella* and *P. interpunctella* larvae, and *T. confusum* adults, were still alive at the end of the 5 day experimental period which suggests that a degree of gas exchange through both types of overwraps took place. First instar larvae generally died within 48h of confinement.

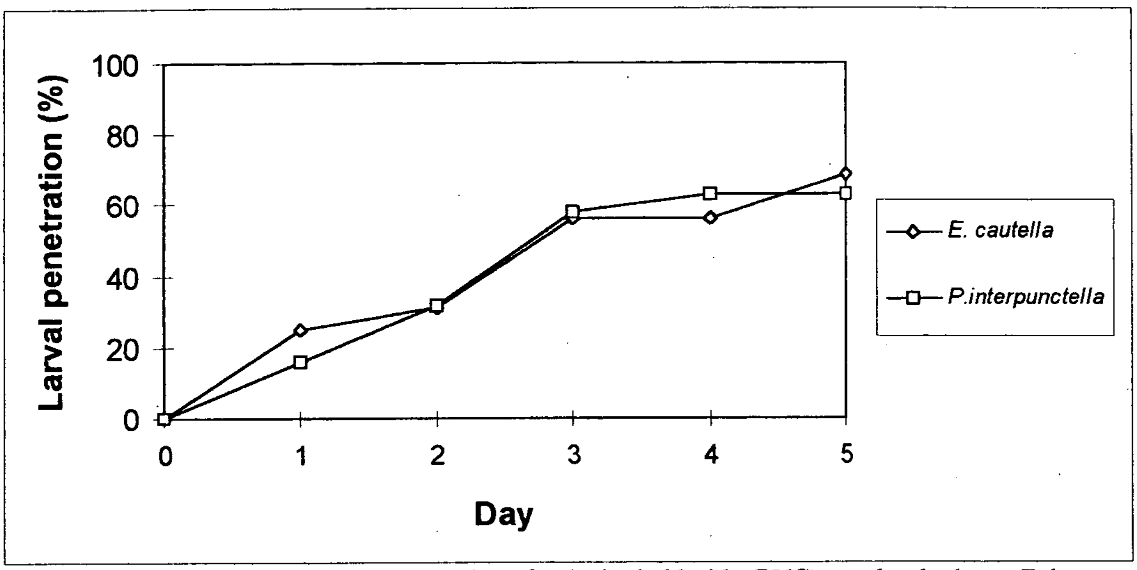


Fig. 20. Cumulative proportion of penetration of polyvinyl chloride (PVC) pouches by large *Ephestia cautella* and *Plodia interpunctella* larvae over the trial period of 5 days.

5.4 DISCUSSION

The results presented in this Chapter have illustrated how certain aspects of phycitine ecology promote the location and invasion of chocolate-based consumables. Firstly, odours escaping from chocolate boxes clearly elicit a positive oviposition response from *Ephestia cautella* and *Plodia interpunctella* females. Importantly, this shows that adult females recognize the contents of a chocolate box as a potential food source for their larvae. Previous studies into the oviposition behaviour of these species have found that the volatiles of other food types also elicit positive responses; both kibbled wheat (Barrer and Jay, 1980) and a larval rearing medium composed of whole wheat, rolled oats, wheat bran and dried yeast (12:3:3:2 by weight) (Barrer, 1977) elicit a positive oviposition response from *E. cautella* females, while Phillips and Strand

(1994) showed that cornmeal volatiles elicit a positive oviposition response from *P. interpunctella* females.

Phycitine females respond to the odours of chocolate-based consumables by depositing a significant proportion of their eggs as close as possible to the odour source; a trait which no doubt maximises the chances of the newly hatched larvae locating the food source. This implies that, to a degree, oviposition response is positively correlated with the concentration of the odour. This was apparent in both the 'chamber' and 'cage' oviposition experiments. In the chamber experiments *P. interpunctella* females deposited a significant proportion of their eggs directly over the outlet tube attached to the container housing the chocolate box, where the concentration of volatiles was no doubt greatest, while *E. cautella* females deposited a significant proportion of their eggs down the outlet tube. In the cage experiments, female *P. interpunctella* preferentially deposited eggs at each end of the chocolate boxes where odour either escaped through artificially made punctures in the overwrap, or, it is suspected, leaked through incomplete package seals. More eggs were deposited directly onto the ends of boxes whose overwrap was punctured than boxes with no such holes, which suggests that the greater volume, or rate, of odour escaping through the punctures allowed the females to deposit their eggs with a greater degree of accuracy. This again suggests a relationship between odour concentration and egg placement. Indeed, females could sometimes locate the punctures with such precision that they were able to project their ovipositor through a hole in the overwrap, and attach their sticky eggs to the inner surface of the film. This is important because larvae hatching from these eggs placed <u>within</u> the confines of the box, must have a high probability of locating the food source, particularly given that larvae are able to orientate toward the source of food odours. Given the apparent low probability of phycitine larvae locating the contents of packaged goods, such an adaptation by *P. interpunctella* females must provide a significant foraging advantage for their larvae.

Given the positive oviposition response that odours from chocolate-based consumables elicit from gravid phycitines, the finding that odours escape from apparent completely sealed assortment boxes has serious implications. If this failure of packaging to retain odours is translated throughout the entire assortment range (and there is no reason to think otherwise as the majority assortment products are overwrapped the same way, with the same film, by the same machinery), then every box can potentially elicit an oviposition from gravid, female phycitines.

The escape of odour from apparently sealed chocolate boxes was thought to be caused by leakage through minute holes at the end of boxes where the overwrap had not sealed completely, rather than permeation through the film itself, for two reasons. Firstly, as has already been discussed, in the 'cage' oviposition experiment, *P. interpunctella* females deposited their eggs exclusively around the ends of the boxes, never along the sides or on top of the boxes. This indicates that the females were responding to a cue(s) associated with the box ends. While the wrinkles and creases on the ends of the boxes possibly explain the attractiveness of oviposition on these surfaces, they do not explain the consistent deposition of eggs on the tray immediately adjacent the box ends. This distribution of eggs on the tray suggests another stimulus is involved, and given the already proven relationship between odour and oviposition, this stimulus is thought to be odour leaking from gaps in the overwrap covering the box ends. If the odours were able to permeate through the overwrap, it would be reasonable to assume that volatiles would permeate not only from the box ends, but also from the other surfaces, and thus, these surfaces would be equally attractive as oviposition sites and, consequently, oviposition would be more uniform over and around the entire box.

Secondly, from personal experience gained through constructing the pouches for the overwrap penetration experiments, combining surfaces of the PVC overwrap via the application of heat does not always result in a complete seal. When a section of the PVC overwrap is folded, and the free edges heat-sealed, minute gaps often remain in the corners where the sealed edges join the folded edge; the forces of the fold act to keep the edges separate. The difficulty in avoiding the presence of minute passages in the angle of folded films was also noted by Anon. (1969). At the time of manufacture, a number of layers of the overwrap are folded and overlaid on the ends of assortment boxes (the 'envelope' fold) before heat is applied. It is possible that, as a result of this folding process, similar small gaps remain in the overwrap of assortment boxes resulting in the escape of odours.

Results from the experiments examining the effect of package integrity on larval invasion, support the theory that small gaps are present in the overwrap of finished assortment products. In these experiments, larvae were found within boxes that had no obvious imperfections in the overwrap, and whose overwrap had not been actively penetrated by the larvae. The larvae must have entered through minute, pre-existing holes or gaps in the overwrap. Anon. (1969) stated that young moth larvae can find their way along the minute passages in the angle of the fold of many films. Therefore, while the presence of these holes has not been confirmed, there is certainly evidence to suggest that they do occur in the envelope folds on the end of assortment products, and that they not only allow the escape of volatiles attractive to gravid phycitines, but that they also act entry points for small phycitine larvae.

Substrate stimuli are obviously important for *P. interpunctella* oviposition, with females preferring to lay their eggs in ridges or crevices rather than on smooth surfaces. The mesh, forming the base and lid of the oviposition chamber, provided an excellent surface for egg laying, and, as already mentioned, the crevices formed in the overwrap covering chocolate boxes, particularly on the ends, also provide attractive sites for oviposition. Indeed, it is probably the combination of odour apparency and an undulating surface that make the ends of assortment boxes highly attractive as oviposition sites.

While only female oviposition responses to product odours were examined in this study, there is evidence to suggest that product odours also draw females to the general vicinity of the odour source prior to oviposition. There are numerous examples of other lepidoptera utilizing airborne stimulants to locate their hosts (e.g. Mitchell *et al.*, 1991; Peterson *et al.*, 1994; Phelan *et al.*, 1991; Renwick and Radke, 1983). Barrer and Jay (1980) showed that a grain source that elicited *E. cautella* oviposition behaviour also attracted gravid females upwind in wind-tunnel assays while Phillips and Strand (1994) also showed that female *P. interpunctella* orient to odours from food sources. In a preliminary wind tunnel trial undertaken by the author (data not presented), gravid female *P. interpunctella* responded positively to odours emanating from the contents of an open box of 250g Roses (twist-wrappers of units removed) by initiating flight, moving toward the source of the odour, and landing on a mesh barrier placed immediately in front of the chocolates. The degree of response was considerably reduced when the box of chocolates was replaced by an identical box packed with tissue paper. While additional experimentation is required to validate the trial results, it is believed that this finding, plus previous evidence of female lepidopteran attraction to airborne stimuli, strongly suggest that odours escaping from chocolate boxes attract phycitine females to the general vicinity of the boxes, as well as eliciting an oviposition response.

Phycitine larvae were also found to respond positively to food odours. While the olfactory responses of *E. cautella* and *P. interpunctella* larvae have not previously been examined, larvae of other lepidopteran species have exhibited similar responses to host volatiles. Using a Y-tube set up similar to that used in this study, Ascoli and Albert (1985) showed that second instar larvae of the eastern spruce budworm, *Choristoneura fumiferana*, were able to detect host odours and move in the direction of the odour stream. Sutherland (1972) showed that, in a closed system, newly hatched codling moth, *Cydia pomonella*, larvae orientated and moved rapidly towards freshly cut apple skin by means of olfaction. Huang *et al.* (1990) found that larvae of the lesser cornstalk borer, *Elasmopalpus lignosellus*, were attracted to volatiles emitted from peanut plant parts. They also showed that this olfactory response depended primarily on the antennae. Ramachandran and Khan (1991) found that rice plant volatiles were an important factor in the reversal of phototaxis of first instar larvae of the rice leaffolder *Cnaphalocrocis medinalis*.

Directional orientation and movement by newly emerged larvae in response to food volatiles may serve two purposes in the infestation of assortment boxes. Firstly, odours escaping from defects in the overwrap may help to guide larvae to the packaging defects and, consequently, into the box, although this might only occur at very close range, that is, when larvae are already in the vicinity of the fault. Larvae of both species responded positively to milk chocolate volatiles, which are likely to comprise for a high proportion of the total volatile matrix escaping from assortment boxes.

Secondly, larvae may use olfaction to locate preferred assortment units once they are inside a box. As previously discussed in Chapter 3, when inspecting infested Milk tray and Roses products returned by consumers, phycitine larvae were almost always found feeding on the whole, shelled, roasted hazelnut contained within 'hazelnut whirl' units. Other units, however, were usually undamaged. This suggested that the larvae had been able to locate the preferred hazelnut whirl unit without sampling a series of units beforehand. The response, particularly from *P. interpunctella* larvae, to roasted hazelnut volatiles, indicates that olfaction might be the primary mechanism used by larvae to discriminate between units once inside an assortments box.

While, *P. interpunctella* certainly showed a strong orientational response to roasted hazelnut volatiles, *E. cautella*, on the other hand, showed little response to hazelnuts, despite the apparent preference for hazelnuts observed in the returned infested goods. This suggests that *E. cautella* foraging behaviour may rely on stimuli other than, or in addition to, olfactory cues. On the other hand, the method used to test larval responses may also have contributed to the apparent lack of *E. cautella* response to roasted hazelnuts and, to a lesser extent, milk chocolate. *E. cautella* appeared to be very sensitive to handling, certainly more-so than *P. interpunctella* larva. It is possible the lack of response by *E. cautella* larvae was more an artefact of the method than an indication of lack of preference.

Like *P. interpunctella* larvae (Mbata and Osuji, 1983), newly hatched *E. cautella* larvae are negatively phototactic. This trait probably has little positive influence on the likelihood of infestation of packaged goods. In fact, in some circumstances it might even help to protect goods from invasion. The results of this study suggest that if a larva hatches close to an odour stream but is exposed to direct light, the larva will generally seek to move away from the light source rather than pursue the odour to its source. Consequently, invasion may be avoided. Other factors, however, such as the colour and shape of objects, might also play a role in phycitine larval movement, and these factors need to be investigated before definitive statement can be made about larval orientation and movement in a given environment.

Which compound, or groups of compounds, identified in the headspace analyses acts as a phycitine attractant, and whether adult respond to the same compound(s) as larvae, cannot be determined without further behavioural assays. Examination of previous studies in this area, however, may provide some clues as to which compound(s) are active in this respect.

The volatile plant kairomones attractive to lepidoptera has been summarised by Metcalf and Metcalf (1992). While none of the compounds listed were found in the headspace of any of the materials tested in this study, phenylacetaldehyde, which acts as an attract for many lepidopteran species (eg. the yellow colared scape moth *Cisseps fulvicollis*, the corn earworm *Heliothis zea* and nine other Noctuidae, the European corn borer *Ostrinia nubilalis* (Cantello and Jacobsen, 1979a,b) and the cabbage looper moth *Trichoplusia ni* (Haynes *et al.*, 1991; Heath *et al.*, 1992)) has been identified as a volatile compound of a variety of roasted nuts, including peanuts, macadamia's and filberts (TNO-CIVO Food Analysis Institute, 1989). Phenylacetaldehyde is also a volatile component of cocoa, the primary ingredient of chocolate (TNO-CIVO Food Analysis Institute, 1989).

Other possible candidate compounds are long chain fatty acids, volatile compounds of almonds that mediate the flight behaviour of navel orangeworm, *Amyelois transitella,* moths (Phelan *et al.*, 1991). All of the fatty acids identified by Phelan *et al.* (1991) are also volatile compounds of roasted peanuts (TNO-CIVO Food Analysis Institute, 1989).

While neither phenylacetaldehyde nor any of these long chain fatty acids were identified in the headspace of roasted hazelnuts or Roses units, this does not necessarily mean they were not present. It is believed that the method of analysis used to test these materials, on behalf of the author, was not sensitive enough to identify all of the constituents of the headspace. By comparing the results obtained in this study for roasted hazelnut volatiles, with those obtained previously for roasted peanut volatiles, an indication of the number, and type, of compounds that may have been present, but were not detected, can be gained. A total of 364 volatile compounds have been identified for roasted peanuts (TNO-CIVO Food Analysis Institute, 1989) whereas only between 30 and 40 compounds in the headspace of roasted hazelnuts were detected in this study. Also, 12% of the compounds identified from roasted peanuts were pyrazines. Pyrazines are compounds that are commonly produced during the process of roasting food, and they give roasted products their characteristic taste and odour (N. Davies *pers. comm.*). They have a very low odour threshold, so that even in trace proportions, their presence can be detected (Brophy and Cavill, 1980). For example, 3-Isobutyl-2-methoxypyrazine, from green peas, has an odour threshold in water of 2 parts in 10^{12} (Siefert *et al.*, 1970). There is little doubt that pyrazines are present in the headspace of roasted hazelnuts, however, the fact that they were not detected in the analysis, and the overall low number of compounds detected (in comparison with roasted peanuts), emphasises the poor sensitivity of the method used in this study to analyse the headspace volatiles of roasted hazelnuts and Roses units.

The analysis of milk chocolate involved taking a larger sample of the headspace (500mL), and thus, could be considered more sensitive than those analyses undertaken on behalf of the author. However, again, compounds expected to be present in the headspace, such as pyrazines, were not detected, so clearly not all constituents of the volatile matrix were identified. Cocoa alone has 505 identified volatile components (TNO-CIVO Food Analysis Institute, 1989), and even allowing for the mixing with other foods and the cooking process, the total number of volatiles in milk chocolate would be expected to be greater than the 48 identified by the Queensland DPI analysis. Therefore, the fact that potentially attractive compounds, such as phenylacetaldehyde and long chain fatty acids, were not detected in the headspace roasted hazelnuts, Roses units or milk chocolate does not necessarily mean they were not present. Clearly, more sensitive techniques need to be employed to ensure that the widest possible range of the volatile compounds of these materials are known before bioassays, to determine phycitine responsiveness, can be undertaken.

Despite the detection of probably only a small proportion of volatiles by the analyses, some of those that were detected have previously been shown to act as kairomones for insects other than lepidoptera. For example, a combination of ethanol, ethyl acetate and acetaldehyde has been found to attract the dried fruit beetle *Carpophilus hemipterus* (Smilanick *et al.*, 1975). Ethanol is also attractive to the bark beetles *Hylobius abietis* (Lindeloew *et al.*, 1993), *Tomicus piniperda* and *Hylurgops palliatus* (Schroeder, 1992). A combination of ethyl acetate and ethanol attracts the nitidulid *Glischrochilus fasciatus* (Lin and Phelan, 1991), while the fungivorous soil collembolan *Onychiurus armatus* is attracted by ethyl acetate (Bengtsson *et al.*, 1991). Hexanal and heptanal act as attractants for the carrot rust fly *Psila rosae* (Guerin *et al.* (1983) while hexanal, heptanal and propanal were attractive to the sawtoothed grain beetle *Oryzaephilus surinamensis* (Mikolajczak *et al.*, 1984). Alpha-pinene is attractive to the bark beetle *Blastophagus piniperda* (Kangas *et al.*, 1965) and the Douglas fir beetle *Dendroctus pseudotsugae* (Heikkenen and Hruitfiord, 1965).

The integrity of the overwrap on assortment boxes clearly influenced the likelihood of infestation by *E. cautella*. This was primarily because newly hatched *E. cautella* were unable to actively penetrate the overwrap, and could therefore only enter boxes through pre-existing holes in the overwrap. The extent of *E. cautella* infestation also increased significantly over time. This finding is in agreement previous studies examining the influence of packaging integrity on insect invasion. Yerington (1978) showed that there was a direct correlation between package seal integrity and the extent and swiftness of infestation, while Mullen and Highland (1988) found that dry milk cartons with major packaging imperfections were significantly more prone to insect infestation than cartons with only minor imperfections or free of imperfections. The integrity of the overwrap was less important in preventing *P. interpunctella* infestation as larvae of this species can actively penetrate the overwrap in order gain entrance to a box, as well as enter through existing holes.

It is possible the presence of larvae within boxes made these boxes increasingly attractive to gravid females of succeeding generations; both *Ephestia kuhniella* (Corbet, 1973) and *Plodia interpunctella* (Phillips and Strand, 1994) gravid females preferentially oviposit on food sources contaminated by conspecific larvae in response to larval secretions. Both these species are closely related to *E. cautella*, so for gravid *E. cautella* females to share this trait is not unexpected. Navel orangeworm, *Amyelois transitella,* moths also preferentially oviposit on mummy almonds already contaminated by conspecific larvae rather than uninfested mummies (Andrews and Barnes, 1982).

Both surveys examining the integrity of the overwrap covering assortment boxes at the time of manufacture revealed that the majority of boxes left the factory with at least one obvious fault (hole) in the overwrap. These boxes are significantly more likely to be infested by *E. cautella*, and probably other *Ephestia* species, than boxes that are free of overwrapping faults. As shown in Chapter 3, *Ephestia* species are responsible for 42% of all infestation complaints, so decreasing the number of boxes manufactured with overwrapping faults on assortment boxes will obviously reduce the proportion of complaints attributed to *Ephestia* species which, in turn, will lead to a decrease in overall infestation complaints. Decreasing the proportion of boxes manufactured with overwrapping faults may also reduce the incidence of infestation by *P. interpunctella*. While some *P. interpunctella* infestation obviously occurs as a result of active larval penetration, in other cases, larvae utilize pre-existing holes in the overwrap to gain entry. Eliminating this latter mode of entry might reduce the likelihood of *P. interpunctella* invasion.

E. cautella larvae clearly acted to minimize crowding within chocolate boxes by recruiting additional niches (units) in response to increasing larval density. While the apparently deleterious effects of crowding, and the mechanism(s) that regulate larval spacing, have not been determined for *E. cautella*, a number of studies have examined the effect of crowding on the closely related species, *Ephestia kuhniella*. Smith (1969) found that crowding of *E. kuhniella* larvae caused a diminution of adult body size, an apparent delay in development and increased mortality. Corbet (1971) also found that crowding late instar *E. kuhniella* larvae resulted in delayed pupation and pupae and, according to Ullyett and Merwe (1947; cited in Corbet, 1971), lighter moths are less fecund than heavier moths. Corbet (1971) went on to suggest that a larval mandibular gland secretion, released when two fifth instar larvae come into contact, acts as an epideictic pheromone that regulates a number of behaviours including larval dispersal within a prescribed system. Compounds, classified as 2-acylcyclohexane-1,3,-diones, identified from *E. kuhniella* larval gland secretions, were later shown to be oviposition stimulants (Mudd, 1978; Mudd and Corbet, 1973, 1982).

Crowded *E. cautella* larvae probably experience a similar decrease in fitness as that exhibited by crowded *E. kuhniella* larvae. Such strong selective pressures no doubt drive the spacing behaviour of larvae, resulting in the relatively even distribution of larvae observed within the chocolate box system. These selection pressures were apparently strong enough to overcome nutritional preferences for particular units within a box; the hazelnut whirl units were no more preferred than other units. This contradicted observations made when inspecting assortment boxes, infested by *E. cautella*, that were returned to the company by consumers. In these boxes the hazelnut whirl unit was almost always preferred over other units, although the degree of infestation in returned consumer complaints was generally much lower than that attained during the experimental work. Whether larval secretions regulate *E. cautella* larval spacing is, as yet, unknown, although mandibular gland secretions from last instar *E. cautella* larvae contain the same active compounds found in *E. kuhniella* larval mandibular secretions (Mudd and Corbet, 1973).

The results of the overwrap penetration experiments agreed with the conclusions of Highland (1984) that polyvinyl chloride (PVC) polymer films offer poor resistance to penetration by stored product insects, whereas biaxially orientated polypropylene (PP) films have good resistant properties. Some interesting comparisons can be made between this study and Cline's (1978) study into the ability of a variety of stored product pests to penetrate a number of different packaging materials. Cline (1978) found that 'small' *E. cautella* larvae were able to penetrate PVC film, which contradicts the results of this study, despite the width of film used in each study being similar. Cline (1978), however, used second instar larvae, whereas only newly hatched, first instar larvae were used in this study. This suggests that PVC only provides an adequate physical barrier against *E. cautella* during the first larval instar stage, and subsequent instars are able to penetrate the film. Cline (1978) also found that second instar *P. interpunctella* larvae failed to penetrate the PVC film, whereas this study found that first instar *P. interpunctella* larvae could, in fact, penetrate a PVC film. This apparent contradiction may have occurred as a result of the low degree of replication in Cline's (1978) study. Only 25% of first instar *P. interpunctella* larvae penetrated the pouches in this study. Because of this low penetration rate, Cline's (1978) sample, consisting of only 3 replicates, may have been too small. Had additional replication taken place, it is likely that some second instar *P. interpunctella* individuals would have penetrated the PVC film in Cline's (1978) study. Both studies agreed that fifth instar *E. cautella* and *P. interpunctella* readily penetrated PVC film. Both also agreed that PP film is highly resistant to penetration by *E. cautella* and *P. interpunctella* larvae.

The finding that *Tribolium confusum* can penetrate the PVC film confirms the findings of Cline (1978) that so-called 'invader' species (i.e. those that enter packages through existing openings (Highland, 1984)) will act as 'penetrators' (i.e. species that bore through packaging materials (Highland, 1984)) when confined without food. The study also showed that the categorization of *E. cautella* as a 'penetrator' (Highland, 1984) was, in this case, inaccurate as first instar larvae, which are no doubt responsible for most cases of infestation, could only act as 'invaders'. These findings bring into question the utility of categorizing insect pests of packaged goods as either 'invaders' or 'penetrators'. If such a system of categorization is to be maintained, due regard should be given to the differing abilities of insect life-stages to penetrate different packaging materials, with emphasis given to those life-stages most likely to affect infestation.

The results presented in this Chapter have highlighted how differences in the ecology of *E. cautella* and *P. interpunctella* influence the likelihood of each species infesting assortment products. *P. interpunctella* larvae probably have a greater chance of infesting goods than *E. cautella* larvae for two reasons. Firstly, adult females are able to attach their sticky eggs directly onto the box, often very close to a packaging fault. As shown earlier, *P. interpunctella* females can even deposit their eggs within the confines of assortment boxes if package integrity is poor. *E. cautella* eggs, on the other hand, lack a sticky coating that allows them to be positioned with such precision, although there is little doubt that females can still deposit eggs within the immediate proximity of an odour source. Secondly, newly hatched *P. interpunctella* larvae are able to gain entry into goods by either chewing through the overwrapping material or by moving through pre-existing holes in the overwrap, whereas newly-hatched *E. cautella* larvae can only enter through existing holes. These factors might, in part, explain why *P. interpunctella* is responsible for the majority of infestation cases concerning goods manufactured at the Claremont factory.

While there might be slight differences in the ecology of *E. cautella* and *P. interpunctella* with regard to product infestation, the behavioural processes involved in the infestation of assortment products are likely to be essentially the same for both species, and phycitines in general. By combining an understanding of the factors that influence post-packaging infestation with an understanding of the factors that influence pre-packaging infestation (i.e. the presence of *E. cautella* at Claremont; see Chapters 3 and 4), an overview of the processes involved in the infestation of assortments by phycitines can be developed (Fig. 21).

Clearly, the most important factor influencing the infestation of chocolate-based consumables is exposure to phycitines and package integrity. If produce is never exposed to phycitines at either the factory or throughout the distribution network, infestation will never occur and consumer complaints will never arise. However, if produce is exposed to gravid *E. cautella* at Claremont, and in fact, becomes infested prior to packaging, consumer complaints will inevitable ensue.

If produce avoids pre-packaging infestation only to be exposed to phycitines at some stage during distribution, the probability of infestation depends on the integrity of product packaging. Odours that escape through faulty product packaging will attract the attention of gravid phycitines who, recognising the presence of a potential larval food source, will preferentially oviposit on and around the odour source. If positioned close to the odour source, larvae may detect the odour stream and follow it, either entering boxes through a packaging fault, or by actively penetrating the overwrap. If larvae then locate the contents of an assortments box, a infestation-related consumer complaint will inevitably result. If larvae hatch some distance from the odour source, searching activities will probably be random or undirected, and the larvae may fail to locate produce. If however, during such a searching pattern, they happen to encounter the odour stream leading to a packaging fault, or if they penetrate the overwrap by chance, infestation will most likely occur, leading to consumer complaints.

By contrast, produce that is packaged so that all odours are retained within boxes, will only become infested if, by chance, phycitine eggs are deposited nearby and the newly emerged larvae happen to locate the produce and actively penetrate the

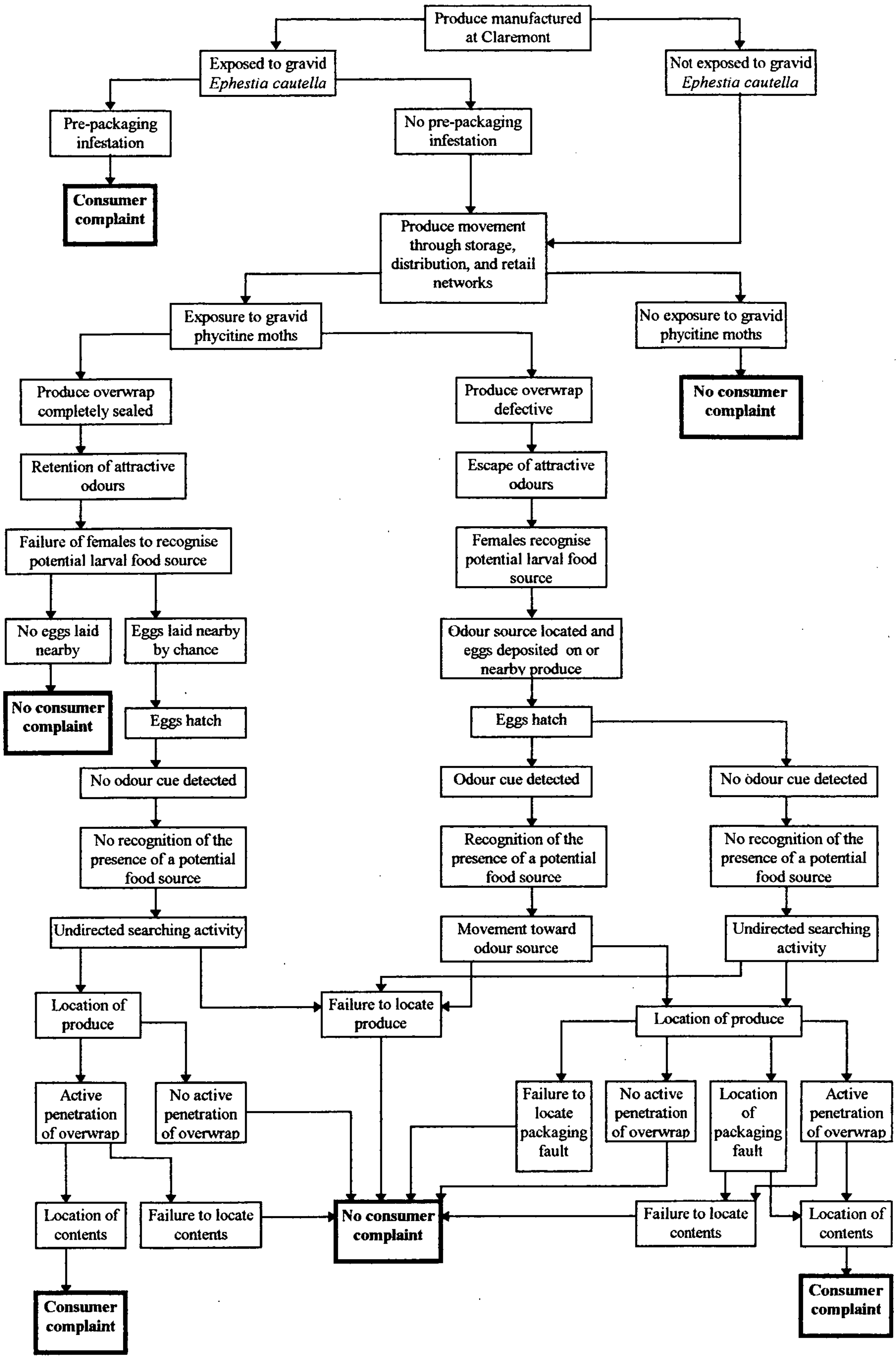


Fig. 21. Overview of the factors influencing phycitine infestation of assortment products.

overwrap. Generally, however, if all odour is retained, the presence of a potential larval food source will be hidden from gravid phycitines so that egg deposition will occur elsewhere. Well sealed produce is probably at greater risk of infestation if stored with poorly sealed produce than if it were stored alone.

Therefore, assortments will only be infested if exposed to phycitines and, if this occurs, produce with faulty packaging is more likely to be infested. Although this study has principally been concerned with the infestation of assortment products, it is likely that these two factors, phycitine apparency and package integrity, are also key elements involved in the phycitine infestation of other product types manufactured at Claremont.

While a detailed discussion of the strategies needed to reduce the incidence of infestation are presented in Chapter 6, it is clear from the results presented in this Chapter that the use of odour retaining packaging needs to be investigated. The feasibility of using an overwrapping film which has insect penetration properties superior to the PVC film (such as PP) should also be investigated. Regardless of the type of film used, the incidence of infestation will fail to decline while the current high rate of overwrapping faults persists. Clearly, quality procedures need to be introduced to minimize the incidence of overwrapping faults at the time of manufacture. The need to implement measures aimed at reducing the apparency of phycitines at the Claremont production plant and throughout the distribution network has already been referred to (see Chapter 3), and is discussed further in detail in Chapter 6.

CHAPTER 6

Reducing the incidence of insect infestation of chocolate-based consumables: general discussion, recommendations and further research

6.1 GENERAL DISCUSSION AND RECOMMENDATIONS

During the course of this research program, many factors that influence the insect infestation of chocolate-based consumables manufactured at the Claremont plant have been investigated. As a consequence, a number of measures necessary to reduce, or minimize, the incidence of infestation have become apparent. These can be broadly defined into two categories: (1) measures to reduce the incidence of pre-packaging infestation, which are primarily concerned with the management of insect pests at the Claremont plant and; (2) measures to reduce the incidence of post-packaging infestation, which are concerned with the prevention of infestation while produce is moving through the distribution and retail network.

6.1.1 Measures to reduce the incidence of pre-packaging infestation

The proposed measures discussed below are restricted to the management of insect pests already resident at the factory. They do not refer to methods of restricting the importation of insects into the factory from outside sources, as present methods appear to be satisfactory. Being situated on an island, any incoming goods (ingredients) are transported by ship. Goods destined for the factory are fumigated prior to leaving their country of origin and, upon arrival, are inspected by quarantine personnel. Most ingredients (e.g. nuts, dried fruits, flour) are then fumigated again by factory personnel before entering the facility proper. During the author's time at the factory, no new insect pest species have been introduced. However, the stored product pests presently found at the factory were no doubt brought onto the site via the importation of contaminated goods some time in the past, and the presence of these pests should act as a reminder of the ever-present threat of invasion by 'external' insect pests is real.

(i) A proposed alternative insect pest management strategy

Obviously, the way to ensure that pre-packaging infestation does not occur is to create an insect pest-free environment within the Claremont plant. However, it is clear from the results presented in this study that the current strategy of controlling insect pests, in particular the almond moth *Ephestia cautella*, at the factory via the regular blanket application of synergised pyrethrins is incapable of achieving this goal and, therefore, insect pest management need to be re-evaluated.

Not only is the effectiveness of this method in reducing insect population numbers questionable under present conditions, but there are a number of other aspects of this strategy that are of concern. Firstly, repeated use of the pesticide in food production areas without covering food and food handling equipment (contrary to the application guidelines) presents a real threat of product contamination. Secondly, there is little regulation of the volume of pesticide used; the correct dose is not calculated prior to delivery, and no attempt is made to determine the volume that is actually delivered, or whether target organisms are reached. Overdosing with the pesticide increases the risk of product contamination, while underdosing reduce the effectiveness of the chemical and promotes insect resistance. Thirdly, in addition to these methodological failings, the equipment used by the Pest Control Officer (PCO) to hand-spray pyrethrins is also inappropriate. As shown in Fig. 1, the equipment used consists of large pesticide cylinders (~85kg each when full) placed on a small, two-wheel trolley. A release system, fashioned from piping and outlets used in the 'fixed' release systems, delivers the pesticide from one cylinder. Because of the angle at which the gas is released from this apparatus, the PCO is required to walk backwards to avoid the stream of gas. This is clearly an unsafe work practice. The correct hand-spraying equipment consists of a single, small cylinder of pesticide placed on a trolley with the pesticide released through a flexible hose and gun attachment. Guns that deliver a prescribed volume of the pesticide are also commercially available. If the practice of hand-spraying pyrethrins is to continue, the PCO should be provided with the correct equipment.

Additional problems associated with the application of pyrethrins in the factory environment were described in Chapter 4. Briefly, these included: (1) that pyrethrins only affect exposed insect stages while most insect growth and development occurs in non-exposed refuges; (2) treatment does not coincide with peak adult activity; (3) poor room sealing leads to incomplete coverage and, probably, sublethal doses; (4) the length of time between routine applications is sufficient for significant copulation and oviposition behaviour to take place and; (5) at times of peak production, periods between application are often protracted.

Fig. 1. Pest Control Officer applying synergised pyrethrins.

While all of the above factors obviously draw into question the utility of such a pest management strategy, the primary criticism of the strategy is that it fails to address the root cause of the problem, which is poor hygiene practices in certain areas of the factory (see Chapter 4). As stated by Anon. (1969), while supplementary methods (e.g. the application of pesticides) have their place in insect pest control, reliance upon them in the absence of good hygiene will prove both costly and relatively ineffective. This appears to be the case at Claremont, where the over-reliance on pyrethrins, without adequate sanitary back-up, has led to only moderate control at great cost. Improving sanitary procedures, particularly in rooms identified in this study as being areas of high *E. cautella* activity, holds the key to reducing insect populations at the factory. Therefore, it is recommended that management move away from the present reliance on chemical-based control and adopt an insect pest control strategy based upon advanced detection methods and improved hygiene procedures, supported by appropriate management structures to ensure tasks are efficiently and satisfactorily carried out. Such a strategy is developed below, and consists of 5 major components: (a) the use of pheromone traps to monitor the *E. cautella* population and detect development sites, (b) regular inspections by the PCO and employee participation to detect *E. cautella* and other insect pest activity, (c) the implementation of appropriate sanitary procedures to eradicate local infestations and prevent the occurrence of potential infestations, (d) adequate internal reporting and response protocols and (e) raising the status of the PCO and pest control generally.

(a) Detection and monitoring of *E. cautella* by pheromone trapping

The suppression, or preferably eradication, of *E. cautella*, from the factory is of primary importance for two reasons. Firstly, this species poses a direct threat to manufactured produce, with the population at the factory probably directly responsible for a small proportion of infestation-related consumer complaints (see Chapter 3). Secondly, there is evidence that this species is radiating from the factory through the distribution network (see Chapter 3). Therefore, it is recommended that a pheromone trapping system to monitor *E. cautella* activity, as trialed in this study, be incorporated into future pest management programs. Not only did the trialed system identify the distribution of *E. cautella* within the factory, but it also readily detected

E. cautella breeding sites. Thus, the system can be used as a tool to accurately target control measures, regardless of whether they are chemical or sanitary-based. By monitoring fluctuations in population numbers over time, the system can also be used to evaluate the effectiveness of control strategies. Even if *E. cautella* was successfully eradicated from the factory, a well maintained pheromone monitoring system would act as an early warning system against the re-infestation of the factory by *E. cautella* or other types of storage moths [the pheromone lures attract a variety of storage moth species] (Burkholder, 1974).

(b) Detection and monitoring of general insect activity

Monitoring the activity of other insect pests present in the factory, via trapping, could also potentially be undertaken; traps and attractants are commercially available for the confused flour beetle *Tribolium confusum* and the German cockroach *Blattella germanica*, although pheromone attractants for the sawtoothed grain beetle *Oryzaephilus surinamensis* are not yet commercially available (Phillips, 1994). However, from personal experience, these traps are not particularly practical for use in the factory environment because, being situated at ground level, they tend to be swept up, thrown-out or water damaged within a short space of time. As these insect species are also considered less of a threat to finished product than *E. cautella*, it is considered that full scale trapping programs to monitor population activities are not necessary. Rather, residual populations of these type of insect pests could be adequately detected via routine inspections of the factory by the PCO (as currently undertaken) and by employee participation in the form of reporting insect infestations or sightings to the PCO (which presently occurs only infrequently).

Currently, the factory's employees are an under-utilized resource for monitoring insect pest activity. The lack of feedback from personnel concerning insect pests is, in part, due to a lack of knowledge about insects pests, their control or the potential harm they can do to finished product and, hence, company image. Instituting a program to educate staff about the insect pests that occur in the factory as well as informing them about the general structure and goals of pest control at the factory, and their role within that structure, would fill this knowledge gap. By encouraging staff, perhaps with incentives, to promptly alert the PCO of infestations or insect pest sightings and, to ensure that standards of hygiene in their particular work areas are such that the risk of infestation is minimized, insect pest control should become considerably easier to manage and, consequently, quality assurance goals (i.e. no pre-packaging infestation) more readily achievable.

(c) Eradication and prevention of local infestations

The elimination of actual and potential insect breeding sites through improved hygiene procedures constitutes the primary method of control in this proposed management strategy. The importance of appropriate hygiene standards has long been recognised by the confectionery industry (Anon., 1969). Not surprisingly, there is a direct relationship between the standard of hygiene within the factory and the distribution of *E. cautella* (see Chapter 4). This is no doubt the case with other insect pest species as well.

When an local infestation is located, the goal should be the removal of infestations as quickly and efficiently as possible in order to minimize the number of insect pests within the factory. Often this will only require the sweeping up of infested debris or the cleaning of an infested drum or container. Other times the stripping and cleaning of machinery will be required and, in such cases, the fumigation of such machinery may sometimes prove more practicable. Each case will need to be assessed on its merits, however, from observations made during this study, a manual clean up will usually be sufficient to eliminate an infestation pocket.

Due regard should also be paid to the hygiene standard of areas free of infestation. Any area where waste and/or debris is allowed to accumulate is a potential site for an infestation (Anon., 1969). This is not to say that the entire factory needs to be kept immaculately clean; it is recognized that the food production activities undertaken at the factory inevitable lead to some spillage and untidiness. It is also recognized that most areas of the factory already have quite good standards of hygiene. However, by taking preventative measures to ensure that poor hygiene conditions are minimized should help to limit the incidence of insect pests throughout the factory. In particular, any spills or debris should be cleaned up promptly, and waste produce or produce to be re-worked should not be allowed to stand for extended periods. Such basic hygiene procedures are outlined in greater detail in general texts concerning sanitation issues in food handling environments (e.g. Troller, 1983), while Anon. (1969) provides specialist information regarding cleaning equipment and routines necessary to achieve the appropriate level of hygiene in confectionery plants. These general housekeeping measures should be implemented regardless of whether the proposed alternative pest control strategy is adopted or not, particularly in the rooms identified in this study as being areas of high *E. cautella* activity.

(d) Internal reporting and response protocols

Employees will quickly lose interest in participating in pest control activities if reporting procedures are made too complex, or if reported insect sightings are not acted upon promptly. Consequently, adequate reporting and response protocols need to be established concurrently with any program aimed at educating and integrating staff into pest management strategies.

At present there is no formal structure through which employees can directly contact the PCO regarding pest sightings or enquiries. Such a structure needs to be put in place, but it must be easy for employees to use. The simplest method of employee contact would be to establish an internal phone extension directly to the PCO. Alternatively, one of the quality departments could act as a conduit between the PCO and employees. The posting of information sheets throughout the factory that clearly identified relevant insect pests and the applicable telephone extension(s) would act to remind employees to be aware, and report the presence of insect pests.

Following the receipt of an insect sighting, the PCO would need to promptly investigate the report, preferably discussing the sighting with the relevant employee, and take whatever action is necessary. Ensuring that a record of each insect sighting/infestation was kept would aid in the evaluation of current, and plan future, pest control strategies.

The establishment of a response protocol, to be followed in the event of a local infestation being detected, would help to ensure the prompt removal of infestations. At present, insect infestations are often detected, but are not promptly dealt with, and may remain in position for many months, or fail to be removed at all. Consequently, considerable, and often needless, pest multiplication and dispersal takes place. A protocol that outlined areas of personnel responsibility, and the various options available to the PCO if sanitary responses were either not carried out, or could not be carried out satisfactorily, would help to eliminate such delays and ensure that the PCO always had an avenue of recourse if difficulties arose.

(e) Raising the status of the PCO

As stated previously, many infestation removals and simple clean-up tasks are often delayed for many months because the departmental personnel responsible ignore the PCO's requests for action. This occurs because the PCO position is not recognised as, or accorded the status of, a management or supervisorial position which, in fact, it is. At present, when requests are ignored, the only recourse for the PCO is to appeal to higher management, and, if still no action results, the problem inevitably remains unsolved. Raising the status of the PCO to a level equivalent to that of other quality control/assurance personnel would no doubt reduce such instances of non-compliance and, consequently, reduce the reliance of the PCO on higher management leading to a more efficient and autonomous pest management structure.

The flow chart in Fig. 2 compares the structure of the present insect pest management strategy with the proposed strategy. Presently, following the detection of an insect pest or infestation, the relevant employee may or may not contact the PCO. [The dashed lines on the arrows represent this uncertainty of action while solid arrow lines represent a more assured pathway]. Without formal reporting procedures, a large proportion of such sightings are probably not immediately reported. If, however, a report is received by the PCO, an inspection ensues. If an infestation is located, the PCO may remove the infestation himself or request departmental personnel to do so. Again, departmental personnel may or may not carry out the requested action. As already mentioned, the PCO carries little status, so that tasks are often not carried out satisfactorily, or at all. When this occurs the PCO might contact upper management if it is deemed essential that a particular task be carried out. If upper management can then find the time, and opportunity, to contact the relevant departmental personnel, the task might then be completed. However, such a convoluted system takes time to work through, and if the problem is still not satisfactorily dealt with (upper management generally does not have time to ensure tasks are actually carried out), the PCO will eventually give up. If either this scenario occurs, or if the eradication of the infestation is beyond the means of the PCO and departmental staff, the infestation remains in place and it is hoped that the regular blanket application of pyrethrins will keep the population suppressed.

By contrast, such situations would be dealt with quite differently under the proposed system (Fig. 2). By educating employees, implementing clear reporting protocols and perhaps offering incentives, a detected insect pest or infestation is more likely to be promptly reported to the PCO. An inspection by the PCO and discussion with the relevant employee would then ensue. If an infestation is located, the PCO may remove the infestation himself or request departmental personnel to do so. By raising the status of the PCO, departmental staff are more likely to comply with PCO requests. Also by documenting the details of the infestation (location, proposed method of removal etc.), departmental personnel might be more inclined to carry out the requested task, as a record of the PCO's request would exist. These steps to increase compliance would negate the need of the PCO to rely upon upper management. If neither the PCO nor departmental staff were able to eradicate an infestation, the PCO would have access to expert assistance to either advise on a course of action to take, or to aid in the eradication process. In addition to utilizing staff to monitor insect activity, a pheromone monitoring system would inform the PCO of the distribution of *E. cautella* throughout the factory, and aid in the detection of local infestations which, again, could then be appropriately treated. Accurate insect monitoring and record keeping would allow the PCO to target pesticide usage at only those areas that required treatment, thereby significantly reducing the total volume of pesticide applied within the factory.

The advantages of the proposed insect pest management strategy over the present strategy are clear:

- Insect pests would be recognised and reported promptly to PCO.
- PCO would have access to detailed information concerning *E. cautella* activity.
- PCO would have expanded treatment options.
- PCO reliance on upper management would be diminished.
- Treatment/removal delays would be reduced or eliminated.

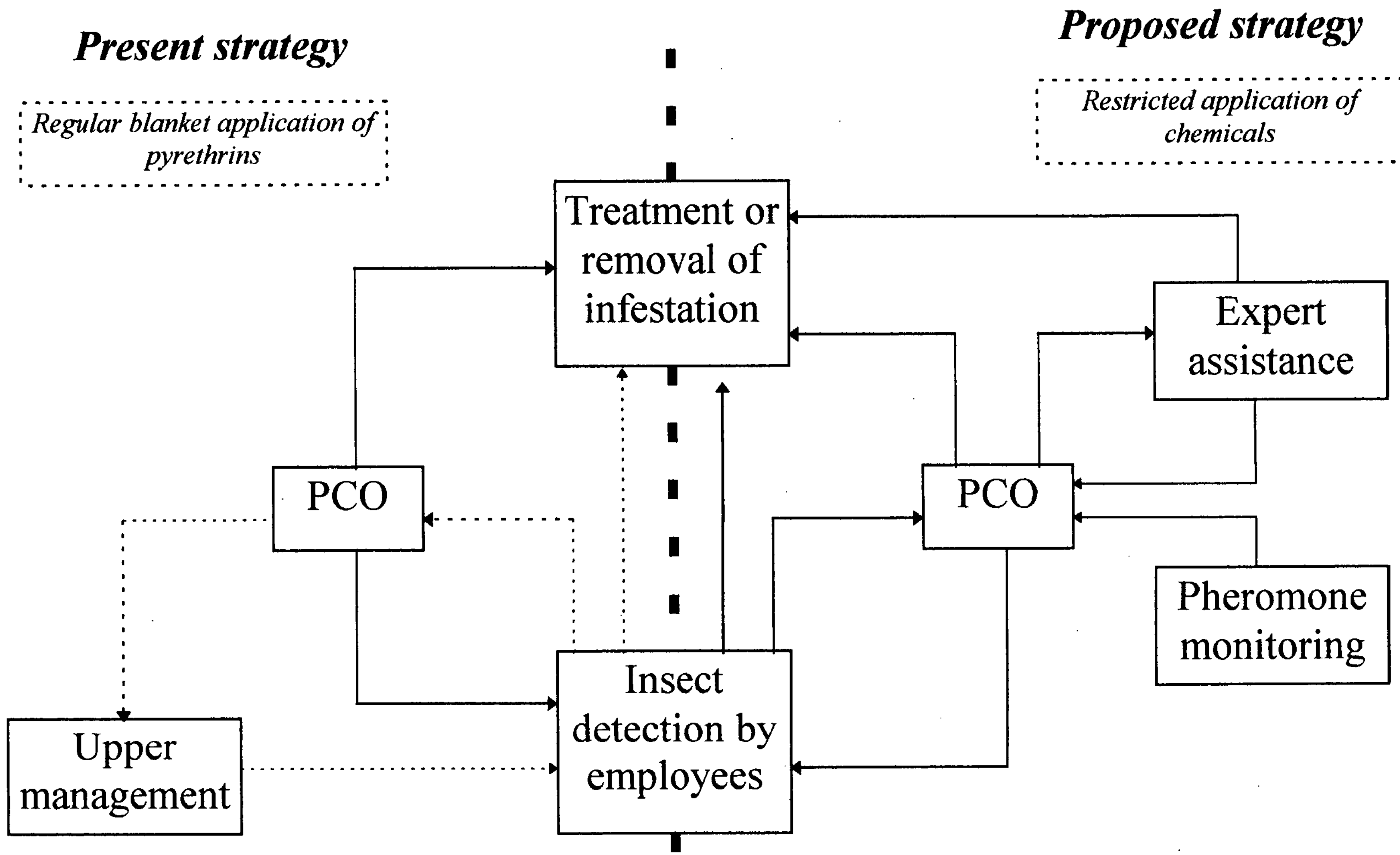


Fig. 2. Comparison of the present and proposed insect management strategies. PCO - Pest Control Officer.

- The root cause of infestation (poor hygiene) would be treated leading to improved control.
- Improved control could potential eradicate insect pest species thereby eliminating the potential of pre-packaging infestation.
- Insect pest control activities would be accountable.
- The use of pesticides would be significantly reduced (by ~80-90%).
- The risk of product contamination would be reduced.
- A 'clean and green' working environment would be provided for staff and manufacturing.
- Equipment used (e.g. pheromone traps) would be simple to operate and maintain.
- The potential would exist to expand the strategy to include vertebrate pests (e.g. rodents, birds etc.).

(f) Comparative cost estimates of present and proposed management strategies

While the author does not have access to all economic data concerning insect pest control costs at the factory, a brief comparison between the primary costs of the present and proposed pest management strategies illustrates that not only could the proposed management strategy provide increased control efficiency, but it could also provide significant cost savings.

As shown in Table 1, the primary costs involved in insect pest control are materials and labour. It must be noted that while synergised pyrethrins are the only 'material' listed in Table 1, dichlorvos and aerosol sprays (generally pyrethrin based) are also applied periodically to certain areas of the factory. While the author has no details of the costs associated with these products, they are presumed to be a fraction of the cost of pyrethrins, based on the considerably lower volumes applied over a 12 month period. Methyl bromide is also used to fumigate incoming goods, although methyl bromide costs were not included in Table 1 as this pesticide is not used within the factory to control existing insect populations.

Table 1. Comparison of the primary costs (p.a.) between the present insect control program and the proposed strategy.

		Strategy	
		Present	Proposed
Materials ($)	Pyrethrin	47 772*	9 554†
	Pheromone trapping	-	2 750‡
Labour ($)	Pest Control Officer	35 000^	35 000^
Total ($)		82 772	47 304
Saving ($)			35 468

* Average cost of synergised pyrethrins 1989-1993.

† Cost of synergised pyrethrins following an 80% decrease in volume applied (from 1989-1993 costs).

‡ Total cost of pheromone traps and lures used during the 12 month monitoring trial and mass trapping study.

^ Pest Control Officer's wage as estimated by the author.

It is estimated that approximately $35 000 p.a. could be saved by adopting the proposed strategy (Table 1). The principle cost savings could be achieved by reducing the volume (by an estimated 80%) of synergised pyrethrins delivered throughout the factory through better targeting of application. Obviously, if pyrethrin treatment ceased altogether, the savings would be even greater.

The recurrent material costs associated with pheromone trapping are only a fraction of the costs associated with the blanket application of synergised pyrethrins. The figure in Table 1 also includes traps and lures used in the mass trapping experiment, which would not be a part of a standard monitoring system.

Improving sanitary procedures are unlikely to provide an additional cost burden; by raising employee awareness and implementing appropriate reporting and response protocols to facilitate the prompt removal of local infestations, insect pest prevention and control should become a speedy, efficient process that is part of the day to day factory activity. If it was necessary to institute addition control measures (e.g. the fumigation of a piece of machinery or a room), this would be an additional cost, although such costs would still be likely to be well below present estimated expenditure.

Under the proposed alternative strategy, the duties undertaken by the PCO would be altered slightly. More emphasis would be placed on inspection, data collection and collation, liaising with staff and, of course, the implementation of control measures. A number of these duties are already undertaken by the PCO, and the time spent performing additional duties would be more than compensated by a reduction in the time spent hand-spraying pyrethrins. Therefore, labour costs would not be expected to rise as a result of the adoption of the proposed strategy. In fact, labour costs might even be reduced as most of the tasks associated with the alternative strategy can be undertaken during normal working hours, thereby reducing the more costly after hours labour presently undertaken.

It is likely that there would be some start-up costs associated with the implementation of the proposed strategy, such as drafting the necessary protocols and education material, although these once-only costs are difficult to quantify.

Therefore, in contrast with the present pest control strategy, the proposed strategy not only has the potential to provide effective insect pest control that is safe, accountable and easy to operate and maintain, but it could also significantly reduce direct pest control costs at the factory. If a higher degree of insect pest control were to be achieved at the factory through the adoption of the proposed strategy, there would obviously be a reduction in factory-based infestation leading to concomitant savings in indirect (avoidable) costs (see Chapter 2).

(ii) Role of the PCO

It is apparent that the PCO is both under-trained and under-resourced to carry his duties to the fullest. It is of credit to the PCO's diligence, common sense approach and willingness to experiment that pest control at the factory has achieved its present standard. However, the PCO could carry out his job even more effectively with training in the following areas; basic entomology, pesticide handling, modern pest control techniques, and computer literacy (spreadsheet, graphics and word processing). The PCO should also be provided with the appropriate equipment with which to carry out his duties. As has already been shown, the equipment and methods used to hand-spray pyrethrins are highly inappropriate. The PCO should also have access to relevant and up to date literature and, as already stated, access to expert help should situations beyond the PCO's experience arise. Regardless of the pest control strategy adopted at the factory, adequate training and resourcing of the PCO is essential.

Another aspect of the PCO's present role that needs attention is the lack of adequate documentation regarding work practices currently undertaken. All local knowledge concerning pest control at the factory is held by the PCO. This means that should the PCO leave the company without passing on or documenting this knowledge, a future employee taking up the PCO position would have to start from scratch, with no reference material on which to base his/her activities. Inevitably, the pest control situation at the factory would deteriorate until the new PCO acquired the relevant experience, which might take years. It is therefore recommended that either the PCO document his work practices thoroughly, or other factory personnel be made fully familiar with the PCO's activities.

It is also recommended that the PCO keep a record of insect pest occurrences throughout the factory, and that these records be collated, analysed and audited regularly. This would not only establish a useful reference database to plan current and future control strategies, but it would introduce a degree of accountability into the pest control area. At present, the only means by which the PCO control activities are assessed is by reference to the number of infestation-related consumer complaints received by the company compared with previous years. However, as has been highlighted in this study, most consumer complaints of this type have their origins externally to the factory, and other factors, such as packaging alterations, also influence fluctuations in the number of consumer complaints. Therefore, infestation-related consumer complaints are not an accurate measure of the success, or otherwise, of pest control strategies at the factory. Only by regularly monitoring insect pest populations and recording instances of pest occurrence can an accurate picture of the effectiveness of pest control strategies be determined.

The PCO's responsibilities should also be extended to hygiene monitoring as the standard of hygiene around the factory ultimately determines the degree of insect control the PCO can achieve. Again, the simple reporting and collating of data on hygiene standards would help the PCO to plan current and future control strategies.

(iii) Ancillary measures

There are other measures that can be taken which will also aid in the management of insect pests and help to reduce factory-based infestation of finished product. Firstly, exposed product should not remain on production belts between shifts and over weekends. This problem was only observed in the assortment packaging section of the factory. While individual assortment units, yet to be packaged, were always returned to cool rooms, open, half-filled assortment boxes sometimes remained on conveyor belts, obviously waiting to be finished by the following shift. Such situations allow any gravid *E. cautella,* in the room at the time, to deposit eggs directly onto product that is already partially packaged. Other insects, such as the coleopteran species present at the factory, may also crawl or fly into the open boxes. Therefore, it is recommended that partially packaged produce be removed from production lines at the end of a shift, provided another shift does not begin immediately. Alternately, the end of a packaging run could be timed to finished at the end of a shift so that, again, no partially packaged product remains on the belts.

Secondly, improving the integrity of the factory by fixing or replacing broken window panes and doors when they occur, and sealing gaps that are left in walls and ceilings when piping is either installed or removed, will not only restrict the active movement of insect pests into and around the factory (e.g. Anon., 1969; Troller, 1983) and improve the efficacy of space treatments (such as pyrethrin fogging), but it will also help restrict entry into the factory by bird pests. Other structural precautions routinely recommended (e.g. Anon., 1969; Troller, 1983) to exclude insect pests (e.g. sealing cracks, cavities or holes in ceilings walls and floors) should also observed.

By introducing cooling systems into warm factory areas, the current employee practice of leaving doors and windows open during hot weather would be unnecessary, further improving factory integrity. Cooling very warm rooms would also limit insect pest growth and development (Anon., 1969). For example, in room Z, where the temperature remains at a constant 29(±4)°C year-round, *E. cautella* development from egg to adult takes approximately 29 days (Bell, 1975; Burges and Haskins, 1965). However, if the temperature in this room was reduced to a more ambient 20°C, *E. cautella* development would take between 59 and 74 days to complete (Bell, 1975; Burges and Haskins, 1965). Therefore, cooling warm areas of the factory would not only negate the need to leave doors open, thereby improving factory integrity, but it would also suppress insect pest populations (Anon., 1969). Thus, it is recommended that a program to improve factory integrity and introduced cooling systems to the warmest sections of the factory be implemented.

6.1.2 Measures to reduce the incidence of post-packaging infestation

From the results presented in this study, it was clear that most infestation occurred after produce had been packaged and had left the Claremont factory. Investigations revealed that some factors that influence the likelihood of infestation (e.g. when produce is manufactured and where it is sold) are either beyond the control of the company or impractical to regulate. There are, however, some obvious measures that can be taken to minimize the incidence of post-packaging infestation, and these are discussed below.

(i) Educate wholesalers and retailers about the dangers posed to goods by stored-product insects

The most effective way to ensure produce does not become infested is to safeguard against exposure to stored-product insects. It was estimated that most infestation of produce occurred while stock was in the hands of independent wholesalers and retailers. Therefore, it is recommended that a program aimed at raising the awareness of stored product insects among wholesalers and retailers be implemented. Information supplied should include: illustrations and descriptions of common stored products insects; examples of the type of damage to packaged goods such insects can inflict; relevant factors that influence infestation (e.g. poor stock rotation practices); general control techniques and; contacts through which additional information or expert assistance can be accessed if required. It should be also emphasised that it is in the best interests of the food industry in general (manufacturers and suppliers) to minimize the occurrence of product infestation by keeping premises free of stored-product insects. While individual wholesalers and retailers suspected of contributing to the infestation problem could probably be identified through a rigorous analysis of the relevant databases, it is recommended that information packages not be restricted to these operators, but be distributed as widely as possible.

(ii) Investigate the use of alternative packaging materials and/or technologies to minimize the escape of volatiles and insect penetration

The study showed clearly that volatiles from foodstuffs manufactured at the factory elicited positive behavioural responses from phycitine adults and larvae. Therefore, in order to conceal the presence of a potential food source (company produce) from phycitines, it is essential that all odours be retained.

Present techniques for packaging assortments fail to achieve complete odour retention. It is believed that odour escapes through minute passages in the angles of the envelope-type overwrap folds on the ends of boxes. If the current technology being used to overwrap assortment products cannot be modified to eliminate the escape of odours, then the feasibility of using alternative packaging technology should be investigated. The odour barrier qualities of materials used to package other product types (e.g. moulded and bar products) should also be investigated.

Attention also needs to be paid to the physical barrier qualities of packaging materials. It was evident that the PVC material used to overwrap assortment products is readily penetrated by several stored product insect species. Tests with an alternative polypropylene film showed that it had vastly superior insect resistance qualities, however this film is apparently unsuitably for use in the domestic market because it is not a shrink-wrap (J. Hey *pers. comm.*). At the time of writing, however, the company was investigating the overwrapping qualities of another biaxially orientated polypropylene (20μm thick), that was a shrink-wrap, to replace the PVC film. Based on the results of this study and others (Cline, 1978; Yerington, 1975), this film should provide superior resistance against insect pests than the PVC, although this needs to be verified through experimentation. If this film fails to provide an improved barrier against insect pests, it is recommended that a program to screen alternative overwrapping materials be implemented, to find a film that not only provides a formidable barrier against insect pests, but also meets the needs and tastes of the market and can be readily applied using the current packaging technology. The physical barrier qualities of materials used to package product types other than assortments also needs to be evaluated.

(iii) Minimize the occurrence of obvious and recurrent packaging imperfections

Regardless of how resistant packaging materials are to stored-product insects, infestation will still occur if product packaging is not sealed completely. This study showed a direct correlation between the incidence of packaging imperfections and the likelihood and severity of infestation. It was also found that Indianmeal moth, *Plodia interpunctella*, females were able to locate, and deposit their eggs through packaging imperfections, thereby maximising the probability of larvae locating the food source. Surveys of package integrity revealed that a high proportion of assortment products contain at least one type of packaging imperfection at the time of manufacture. It is clear that by minimizing the incidence of such packaging faults, the likelihood of infestation will be reduced. It is therefore recommended that quality control procedures be introduced to monitor package integrity.

It is also recommended that an investigation be undertaken to examine ways by which the incidence of packaging faults can be minimized. Recurrent faults were often observed on assortment products from the same production run, which suggests errors in the configuring of machinery prior to a run. Configuring measurements and methods should be standardised, and dummy runs should always be undertaken prior to a run to ensure that packages, at least initially, are free of imperfections. Regular monitoring should then detect whether adjustments are required during a run. While these recommendations are aimed primarily at the production of assortment products, the packaging integrity of other product types should also be investigated and monitored.

(iv) Ancillary measures

As nut ingredients appear to be the preferred food source of phycitine larvae, it is recommended that the roasted hazelnuts contained in the 'hazelnut whirl' assortment units be completely encased by chocolate, as this appears to deter feeding, perhaps by masking the attractive nut volatiles.

When making decisions regarding packaging materials and methods, it should be kept in mind that creased, folded or wrinkled surfaces are actively sought by gravid

P. interpunctella females as oviposition sites, and phycitine larvae in general, as pupation sites. By producing package surfaces free of such undulations, the attractancy of goods will be reduced.

Efforts should be made to ensure that, where ever possible, stock is displayed in open, rather than confined, areas in order to avoid the accumulation of odours escaping from produce. It is suspected that high concentrations of attractive odours are more likely to result in phycitine eggs being laid close to produce. This, in turn, increases the likelihood of product infestation.

6.2 SUMMARY OF RECOMMENDATIONS

6.2.1 Change the emphasis of insect pest management at the Claremont plant from one reliant primarily on chemical-based treatments (principally synergised pyrethrins) to a strategy based upon advanced insect pests detection methods and improved hygiene procedures, supported by appropriate management structures to ensure tasks are efficiently and satisfactorily carried out.

6.2.2 Ensure that the PCO is appropriately trained, resourced, and has access to relevant literature and expert assistance.

6.2.3 Ensure that the methods and work practices undertaken by the PCO are either fully documented, or that other employees become familiar with relevant pest control tasks.

6.2.4 Ensure that accurate records, regarding the incidence of insect pests and hygiene standards throughout the factory, are kept in order to assess the efficacy of current control strategies and plan future programs.

6.2.5 Remove all product from production rooms when manufacture is not in progress.

6.2.6 Improve the integrity of the factory structure and introduce cooling systems into very warm working environments.

6.2.7 Educate managers and workers in the distribution and retail networks about the dangers that stored-product insect pests pose to stored goods, and methods to minimize the occurrence of insect pests.

6.2.8 Investigate the use of alternative packaging materials and/or technologies to minimize the escape of attractive food volatiles.

6.2.9 Investigate the use of alternative packaging materials to minimize insect penetration.

6.2.10 Incorporate the monitoring of package integrity into the routine quality monitoring activities presently undertaken at the factory, and investigate methods of reducing the incidence of recurrent packaging faults.

6.2.11 Ensure that the whole roasted hazelnut, contained in 'hazelnut whirl' assortment unit, is completely encased by chocolate.

6.2.12 Minimize creases, folds or wrinkled surfaces on product packaging.

6.2.13 Avoid displaying produce in confined spaces.

The implementation of these recommendations should result in a significant reduction in product infestation from present levels, which will consolidate and enhance the company's image as a manufacturer of high quality foodstuffs. However, the degree to which product infestation levels will be reduced is dependent upon the degree to which the recommendations are implemented; full benefits will only be achieved with the complete and ongoing commitment to the implementation of all recommendations.

6.3 REVIEW OF STUDY AND FURTHER RESEARCH

While I believe that the research undertaken during this study has fulfilled most of the key objectives originally defined, if given the time over again, with the knowledge I have since acquired, there are a numbers of aspects of the study I would do slightly differently.

Firstly, I would have undertaken additional experiments, to complement those that were undertaken, in order to gain a greater understanding of certain elements of the infestation problem. For example, I would have sampled throughout the distribution network more extensively; had I known the other interstate Cadbury distribution centres (in TAS, VIC, NSW and QLD) were to become redundant, I would have sampled them earlier in the study. Some further sampling of independent wholesale facilities would have also been useful, although I'm not sure that I would have been granted access. Extensive sampling of retail outlets was well beyond the scope of this study due to the sheer number of outlets, however, some selective sampling from outlets, targeted through a more rigorous analysis of the relevant database, may have provided some interesting results. More extensive sampling would have provided a clear picture as to the origins of infestation.

Undertaking a trade audit would have provided a clearer picture of the 'age' of produce in the marketplace. The possibility of undertaking such an audit was investigated, but eventually it was decided that, logistically, such a survey was beyond the scope of this study. Unfortunately, the company was unable to provide any quantitative figures regarding stock 'age'.

Had more infested produce, returned to Claremont by consumers, been inspected, a clearer understanding of the geographic distribution of phycitine species would have been gained, as would a greater insight into phycitine product preferences. Unfortunately, for one reason or another, a significant proportion of returned goods were disposed of before I had a chance to inspect them.

Determining of the resistance status of the strain of *E. cautella* resident at the factory would have provided a clearer picture of the efficacy of control achieved via the blanket application of synergised pyrethrins, which, in turn, would have lead to more definitive conclusions regarding future control strategies. Obviously, if resistance was apparent, any further use of synergised pyrethrins at the factory would be worthless, and alternative insect pest control measures would need to be immediately adopted. A susceptible strain of *E. cautella* was obtained for the purposes of carrying out this work, but unfortunately, problems with culturing this strain prevented the determination of the resistance status of the factory strain.

Wind tunnel trials to determine the long distance attractive qualities of food volatiles would have complemented the oviposition trials and led to a more complete understanding of the host-seeking abilities of phycitines with regard to packaged goods. As mentioned in Chapter 5, a preliminary wind tunnel trial was undertaken, and gravid female phycitines appeared to respond strongly to host (Roses assortments) volatiles, although additional experimentation is required to verify this finding.

Performance studies (on milk chocolate and roasted hazelnut diets) would have complemented larval preference trials and provided a more complete picture of larval host selection. Interestingly, preliminary trials of larval performance on these media indicate that although *P. interpunctella* larvae respond in a very positive fashion to the odour of crushed, roasted hazelnuts, they experience very high mortality levels when confined to a diet exclusively consisting of hazelnuts (data not presented). While this contradicts the performance studies undertaken taken by Johnson *et al.* (1995), this apparent paradox still requires further investigation.

A more complete product risk profile could have been constructed by evaluating phycitine responses to assortment products other than Roses, and to non-assortment products and packaging materials. While I believe the factors that influence insect infestation are essentially similar for most products (e.g. exposure to insect pests and package integrity), variations in product composition, packaging materials and packaging techniques no doubt lead to some variation in the risk of infestation.

Given the opportunity to repeat some of the work carried out in this study, I would refine some of the equipment and methodologies employed. Firstly, I would standardise the contents of all assortment boxes used. Secondly, I would ensure that the age of all insects used for experimentation were known; in the oviposition trials, the age of the females used were not accurately known, and differences in age no doubt led to some variation in the results, as phycitine oviposition behaviour varies with age (e.g. Steele, 1970). Thirdly, for the experiments evaluating behavioural responses to odours, I would replace all plastic components with glass, and provide a filtered air source for the larval preference trials (e.g. Ascoli and Albert, 1985). Fourthly, I would send headspace samples to a laboratory that was equipped to determine all components of the headspace. Finally, if I were able to undertake the mass trapping trial in room Z again, I would conduct a concomitant, independent sampling program in order to properly evaluate the extent of *E. cautella* control achieved via this technique. While I believe that the technique successfully controlled *E. cautella* and, if continued, it would have eradicated this important population, the failure on my behalf to undertake independent sampling ultimately made these conclusions unverifiable. Unfortunately, sampling methods commonly used in previous studies to quantify population changes (e.g. counting the number of moths on walls) were unable to be applied in this experiment due to the low population density. The mark-release-recapture technique (e.g. Hagstrum and Stanley, 1979) would have been the most appropriate method to quantify the apparent population changes.

Having said this, I do believe that the results presented in this study have highlighted many of the key factors that influence the insect infestation of chocolate-based consumables manufactured at the Claremont plant, and, consequently, have led to the formulation of a number of practical, viable recommendations which, if resolutely implemented, should remedy the problem and lead to a superior quality outcome for the company. Interest in this study will possibly go beyond Cadbury Schweppes and into the broader packaged food industry, as the findings and recommendations of this study are no doubt relevant, and applicable, to other food manufacturing companies.

I believe that this study has also made a helpful contribution to the field of stored product entomology. While none of the techniques used in this study offer a novel approach to understanding the ecology of stored-product insects, it is rare to have the opportunity to undertake such a relatively long term examination of this type of problem, with the full co-operation of a manufacturer, and be able to draw together many diverse, influential factors to form a relatively complete picture of the infestation process. Most previously reported studies have been restricted to assessing the infestation of packaged goods on a fragmentary basis, that is, examining only single factors, such as the ability of packaging materials to withstand insect penetration. It is this study's attempt to present a somewhat holistic view of an infestation problem that may be of as much interest to the stored product entomology field as its constituent components.

Some of the individual experiments undertaken will, however, also be of interest to the field. To the author's knowledge, there have been no previous studies examining the oviposition responses of gravid phycitine moths in relation to imperfectly packaged goods, nor to the orientation responses of phycitine larvae in relation food odours. While the findings on these behaviours reported in this study may not be unexpected in light of related studies, they nonetheless add to the knowledge base concerning phycitine behaviour in diverse environments. Possibly the most important ecological finding of this study was that female *P. interpunctella* are able deposit their eggs through packaging imperfections, so that larvae emerge <u>within</u> the confines of a packaged product, thereby maximising their chances of locating the food source. This finding has clear implications concerning the importance of ensuring package integrity.

This study has opened up a number of areas of interest that require further research. Firstly, it appears that phycitines, and no doubt other stored product insect pests, are present, to some degree, in foodstuff wholesale and retail environments throughout Australia. This should be of concern not only to Cadbury Schweppes, but to the food industry in general, as these insects are probably responsible for the infestation of a variety of foodstuffs, not just chocolate-based consumables. As shown in this study, the post-packaging infestation of goods can be costly for companies affected in both economic and image terms. Therefore, more research needs to be undertaken to determine to extent to which stored product insects are distributed throughout food wholesale and retail establishments, so that food producers individually, or the industry as a whole, can evaluate whether control/preventative measures need to be taken to ensure product quality.

This study added to previous evidence (Barrer, 1977; Barrer and Jay, 1980; Phillips and Strand, 1994) indicating the important role that food volatiles play in phycitine attraction and oviposition. By undertaking further research to identify specific volatiles or volatile complexes that attract females, trapping techniques could be significantly advanced. While pheromones have been used for many years to enhance the trapping of male phycitines, little reported progress has made in the quest to discover substances that act as pheromones for female phycitines, except, perhaps for studies that have reported the attractive qualities of conspecific larval mandibular gland secretions (Corbet, 1973; Phillips and Strand, 1994). In the absence of such substances, the identification and commercialisation of food volatile components attractive to female phycitines, may provide a useful aid for trapping females; mass trapping both sexes of a population should be more effective than mass trapping just males (Phillips, 1994). The author concurs with Phillips (1994) who stated that the "potential certainly exists to improve existing trapping technology for stored product insects by the addition of food volatiles to increase insect response to pheromone lures".

It would also be interesting to undertake further research to determine whether the volatiles cues that elicit behaviour responses in adult phycitines are the same as those that elicit responses from larvae, or whether different cues are involved. While this knowledge may not have any immediate practical application, it may be helpful in the future for reducing the incidence of larval package infestation.

Conducting further research into *E. cautella* larval responses to multiple stimuli, such as light and food volatiles, might help to fully understand phycitine larval searching behaviour in food storage/display environments. While this study found that, in choice experiments, larval response to light predominated over response to food volatiles, does this response vary, or is it reversible, after a period of food deprivation? When these two stimuli are combined, do they produce a synergistic action in attracting larvae such as that found by Khattar and Saxena (1978) in *Papilio demoleus* larvae? How do larvae respond to other stimuli such as shape and colour? How do these responses relate to optimal foraging theory? All of these areas would be of interest to explore.

Another area of interest that was visited briefly in this study was the dispersal pattern of *E. cautella* larvae with a box of chocolates. Clearly, there is strong selection pressure for larvae to be well spaced, and the probable reasons for this pressure have already been discussed. What is not clear, however, is the mechanisms larvae use to accomplish this spacing behaviour. Corbet (1971) suggested that mandibular gland secretions from last instar larvae mediated the spatial distribution of *Ephestia kuhniella* larvae in a finite system. Similar compounds have been identified in the mandibular glands of other last instar phycitine larvae, including *E. cautella* (Mudd and Corbet, 1973). However, from observations made during this study, and from preliminary trials undertaken by the author examining the spacing behaviour of *E. cautella* larvae (data not presented), first instar larvae show a similar propensity to be well spaced as do last instar larvae. Therefore, do all larval instars, not only last instar larvae, secrete this epideictic pheromone, and, if not, what other mechanisms are used to mediate spacing? If they do, do the secretions have the same attractive properties for adult females as the secretions from last instar larvae? These aspects of phycitine biology need clarification.

To conclude, further research into the numerous factors that influence the insect infestation of packaged commodities should provide a greater understanding of the processes involved and, consequently, help to ensure that products are delivered to consumers insect-free.

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APPENDICES

Product Group	Product	1990			1991			1992			1993			1994			
		Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Total Complaints
ASSORTMENTS	125g After Dinner Mints	0	116	0.00	0	100	0.00	3	103	0.03	2	102	0.02	2	84	0.02	7
	150g Roses	0	0	-	0	0	-	0	0	-	0	0	-	2	76	0.03	2
	1kg Milk Presentation	1	1	0.72	0	0	-	0	0	-	0	0	-	0	0	-	1
	200g Hazelnut Whirls	39	10	3.72	1	0	-	0	0	-	0	0	-	0	0	-	40
	200g Liqueur Cherries	5	15	0.33	1	15	0.07	1	10	0.10	0	9	0.00	1	7	0.15	8
	200g Milk Chocolate	0	0	-	0	0	-	0	0	-	1	0	-	0	0	-	1
	200g Roses Lantern	0	0	-	0	11	0.00	1	8	0.12	0	17	0.00	11	29	0.38	12
	250g After Dinner Mints	0	155	0.00	1	130	0.01	3	125	0.02	1	114	0.01	0	96	0.00	5
	250g Black Cat	60	92	0.66	91	64	1.43	12	60	0.20	15	32	0.47	2	31	0.06	180
	250g Cabaret	73	103	0.71	73	75	0.98	32	49	0.65	6	39	0.15	0	18	0.00	159
	250g Dark Favourites	227	116	1.95	136	70	1.94	30	58	0.52	46	39	1.18	9	25	0.35	448
	250g Fine Milk Selection	39	10	3.75	31	9	3.30	6	2	2.49	5	0	13.51	0	0	-	81
	250g Hazelnut Whirls	20	66	0.30	44	73	0.60	18	77	0.23	36	71	0.51	44	60	0.74	162
	250g Milk Dark Selection	21	11	1.93	15	7	2.27	1	2	0.51	1	0	12.50	0	0	-	38
	250g Milk Favourites		152		140	102	1.37	45	102	0.44	82	86	0.95	37	60	0.62	304
	250g Milk Tray	140	435	0.32	140	360	0.39	65	402	0.16	93	387	0.24	70	397	0.18	508
	250g Old Gold	45	49	0.91	70	31	2.23	10	20	0.50	5	14	0.35	6	6	1.01	136
	250g Rich Dark Selection	56	11	5.15	23	8	2.87	13	3	4.29	4	0	9.76	0	0	0.00	96
	250g Roses	95	621	0.15	66	649	0.10	47	695	0.07	170	778	0.22	123	889	0.14	501
	250g Valentino	0	16	0.00	1	0	-	0	0	-	0	0	-	0	0	-	1
	375g Fine Milk Selection	10	4	2.35	3	2	1.78	1	1	0.96	0	0	-	0	0	-	14
	375g Milk Florentine	2	0.02	100.00	0	0	-	0	0	-	0	0	-	0	0	-	2
	375g Rich Dark Selection	7	4	1.87	6	2	3.55	2	1	2.00	0	0	-	0	0	-	15
	500g Black Cat	27	21	1.32	13	13	1.04	3	1	3.90	0	0	-	0	0	-	43
	500g Cabaret	42	42	0.99	42	20	2.12	5	6	0.80	0	0	-	0	0	-	87
	500g Dark Favourites	84	37	2.26	33	24	1.37	6	8	0.76	0	1	0.00	0	0	-	123
	500g Fine Milk Selection	10	5	1.87	9	3	3.49	0	0	0.00	0	1	0.00	0	0	-	19
	500g Milk Dark Selection	5	4	1.38	2	2	1.16	0	1	0.00	0	0	-	0	0	-	7
	500g Milk Favourites	80	45	1.78	41	29	1.41	4	14	0.30	2	0	7.41	0	0	-	127
	500g Milk Tray	64	278	0.23	72	223	0.32	25	245	0.10	36	250	0.14	54	259	0.21	251
	500g Old Gold	7	19	0.38	10	6	1.75	2	3	0.65	0	0	0.00	0	0	-	19

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Product Group	Product	1990			1991			1992			1993			1994			
		Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Total Complaints
	500g Rich Dark Selection	12	5	2.26	10	2	4.17	2	2	1.14	0	0	0.00	0	0	-	24
	500g Roses	50	343	0.15	50	294	0.17	45	250	0.18	35	372	0.09	26	423	0.06	206
	500g Roses Tin	0	0	-	0	10	0.00	1	19	0.05	1	13	0.08	0	11	0.00	2
	750g Fine Milk Selection	10	3	3.77	0	0	-	1	0	-	0	0	-	0	0	-	11
	750g Milk Tray	7	49	0.14	9	45	0.20	7	42	0.16	11	42	0.26	12	20	0.60	46
	750g Rich Dark Selection	2	3	0.64	0	0	-	1	0	-	0	0	-	0	0	-	3
	750g Roses	11	59	0.19	12	52	0.23	3	56	0.05	13	42	0.31	8	27	0.30	47
	800g Sweethearts Disp	0	0	-	0	13	0.00	4	18	0.23	0	8	0.00	0	0	0.00	4
Assortments Total		1251			1145			402			565			408			3771
BARS	100g Turkish Delight	1	0	-	2	0	0.00	0	0	-	0	0	-	0	0	-	3
	30g Flake	34	611	0.06	22	502	0.04	30	431	0.07	43	395	0.11	26	352	0.07	155
	30g Peppermint Truffle	0	92	0.00	0	81	0.00	1	69	0.01	0	66	0.00	1	51	0.02	2
	35g Snowflake	0	0	-	0	0	-	0	0	-	0	279	0.00	4	18	0.22	4
	35g Twirl	9	1324	0.01	7	924	0.01	1	1025	0.00	14	892	0.02	6	500	0.01	37
	42g Twirl	0	0	-	0	0	-	0	0	-	0	0	-	2	324	0.01	2
	45g Frys Cherry Cream	1	2	0.41	0	0	-	0	0	-	1	0	-	0	0	-	2
	45g Frys Cream	3	46	0.06	11	41	0.27	1	40	0.02	3	47	0.06	2	40	0.05	20
	45g Frys Five Fruits	12	48	0.25	6	45	0.13	1	41	0.02	9	50	0.18	2	41	0.05	30
	55g Turkish Delight	14	589	0.02	20	577	0.03	13	587	0.02	12	604	0.02	12	561	0.02	71
	70g Four Finger Twirl	0	0	-	0	191	0.00	0	126	0.00	1	97	0.01	3	64	0.05	4
Bars Total		74			68			47			85			58			332
CHILDREN'S	100g Tiny Freddo Frogs	0	0	-	0	0	-	0	40	0.00	1	39	0.03	0	33	0.00	1
	15g Caramilk Bar	0	0	-	0	0	-	0	0	-	0	0	-	1	35	0.03	1
	15g Dairy Milk	2	106	0.02	4	82	0.05	7	78	0.09	5	74	0.07	9	60	0.15	27
	15g Farm Friends	3	38	0.08	0	19	0.00	0	17	0.00	0	16	0.00	0	11	0.00	3
	15g Furry Friends	10	63	0.16	4	40	0.10	4	35	0.11	5	36	0.14	2	34	0.06	25
	2*100g Christmas M-P	0	0	-	0	0	-	1	0	2.38	0	0	-	0	0	-	1
	20G Dairy Milk Agro	0	0	-	0	0	-	0	66	0.00	0	43	0.00	7	29	0.24	7
	220G Agro Cranky Crisp	0	0	-	0	0	-	0	0	-	1	42	0.02	0	5	0.00	1
	30g Flintstones Bar	0	0	-	0	0	-	0	37	0.00	1	3	0.32	0	0	-	1
	4*30g Flintstones Bar	0	0	-	0	0	-	0	28	0.00	1	2	0.55	0	0	-	1

APPENDIX I

Product Group	Product	1990			1991			1992			1993			1994			
		Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Total Complaints
	5*15g Dairy Milk	6	86	0.07	4	88	0.05	2	88	0.02	0	92	0.00	1	81	0.01	13
	5*15g Farm Friends	2	22	0.09	0	22	0.00	0	15	0.00	0	9	0.00	0	5	0.00	1
	5*15g Furry Friends	4	112	0.04	1	113	0.01	0	121	0.00	1	119	0.01	4	117	0.03	10
Children's Total		27			13			14			13			24			91
FOOD	125g Cadbury Cocoa	1	156	0.01	1	163	0.01	0	169	0.00	0	178	0.00	0	166	0.00	2
	250g Cadbury Cocoa	0	257	0.00	0	255	0.00	2	267	0.01	0	253	0.00	2	243	0.01	4
	250g Drinking Chocolate	3	298	0.01	0	308	0.00	2	330	0.01	4	333	0.01	0	332	0.00	9
	250g Dark Cooking	0	158	0.00	2	149	0.01	0	154	0.00	0	146	0.00	0	144	0.00	2
	500g Drinking Chocolate	0	252	0.00	1	288	0.00	0	323	0.00	0	313	0.00	0	319	0.00	1
Food Total		4			4			4			4			2			18
MOULDED	100g Caramello	2	168	0.01	2	167	0.01	0	15	0.00	0	0	-	0	0	-	4
	100g Caramello P-P	0	0	-	0	0	-	0	0	-	0	88	0.00	1	98	0.01	1
	100g Cashew Nut	0	66	0.00	2	52	0.04	0	8	0.00	0	0	-	0	0	-	2
	100g Crisp	0	71	0.00	0	54	0.00	1	0	50.00	0	0	-	0	0	-	1
	100g Dairy Milk	21	722	0.03	4	721	0.01	0	69	0.00	0	0	-	0	0	-	25
	100g Dairy Milk P-P	0	0	-	0	0	-	0	358	0.00	3	380	0.01	2	416	0.00	5
	100g Dark Almond	2	0	-	0	0	-	0	0	-	0	0	-	0	0	-	2
	100g Energy	1	81	0.01	0	67	0.00	1	7	0.15	0	0	-	0	0	-	2
	100g English Toffee	1	30	0.03	0	0	-	0	0	-	0	0	-	0	0	-	1
	100g Fruit & Nut Milk	18	284	0.06	10	302	0.03	3	32	0.09	0	0	-	0	0	-	31
	100g Fruit & Nut Milk P-P	0	0	-	0	0	-	0	203	0.00	15	219	0.07	16	257	0.06	31
	100g Hazel Nut Milk	5	192	0.03	7	197	0.04	11	21	0.52	0	0	-	0	0	-	23
	100g Hazel Nut Milk P-P	0	0	-	0	0	-	2	154	0.01	17	140	0.12	4	147	0.03	23
	100g Hazel Nut Praline	0	0	-	0	0	-	1	0	-	0	0	-	0	0	-	1
	100g Macadamia	0	71	0.00	6	30	0.20	1	0	-	0	0	-	0	0	-	7
	100g Milky White	2	91	0.02	0	81	0.00	0	6	0.00	0	0	-	0	0	-	2
	100g Nut Caramel	4	33	0.12	3	5	0.56	0	0	-	0	0	-	0	0	-	7
	100g Nut Mix	1	47	0.02	2	3	0.58	0	0	-	0	0	-	0	0	-	3
	100g Old Jamaica	1	102	0.01	1	99	0.01	0	12	0.00	0	0	-	0	0	-	2
	100g Peppermint	4	92	0.04	0	92	0.00	1	11	0.09	0	0	-	0	0	-	5
	100g Roast Almond	10	135	0.07	9	125	0.07	1	11	0.09	2	0	-	0	0	-	22

APPENDIX I

Product Group	Product	1990			1991			1992			1993			1994			
		Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Total Complaints
	100g Roast Almond P-P	0	0	-	0	0	-	0	123	0.00	14	108	0.13	5	95	0.05	19
	100g Snack	7	171	0.04	6	172	0.03	1	15	0.07	0	0	-	0	0	-	14
	100g Snack P-P	0	0	-	0	0	-	0	0	-	0	0	-	1	144	0.01	1
	100g Swiss Chalet	0	83	0.00	1	64	0.02	0	9	0.00	1	0	-	0	0	-	2
	100g Swiss Chalet P-P	0	0	-	0	0	-	0	106	0.00	1	111	0.01	4	106	0.04	5
	150g Black Forest	0	0	-	0	0	-	0	0	-	0	0	-	5	0	-	5
	150g Caramello	0	37	0.00	0	0	-	2	195	0.01	5	168	0.03	7	152	0.05	14
	150g Cashew Nut Milk	0	0	-	0	0	-	2	68	0.03	1	1	2.00	0	0	0.00	3
	150g Dairy Milk	0	71	0.00	0	0	-	1	762	0.00	1	702	0.00	6	713	0.01	8
	150g Fruit & Nut Milk	0	45	0.00	0	0	-	2	323	0.01	3	294	0.01	9	332	0.03	14
	150g Hazel Nut milk	0	0	-	0	0	-	3	216	0.01	6	194	0.03	6	231	0.03	15
	150g Milky White	0	0	-	0	0	-	2	76	0.03	1	91	0.01	0	61	0.00	3
	150g Old Jamaica	0	0	-	0	0	-	0	102	0.00	1	95	0.01	0	85	0.00	1
	150g Peanut Milk	0	0	-	0	0	-	0	46	0.00	1	20	0.05	0	0	0.00	1
	150g Peppermint	0	0	-	0	0	-	1	119	0.01	2	113	0.02	3	103	0.03	6
	150g Roast Almond	0	0	-	0	0	-	2	127	0.02	5	118	0.04	7	140	0.05	14
	150g Rocky Road	0	0	-	0	0	-	0	86	0.00	2	32	0.06	1	0	10.00	3
	150g Snack	0	0	-	0	0	-	3	208	0.01	3	203	0.01	4	201	0.02	10
	150g Swiss Chalet	0	28	0.00	0	0	-	1	76	0.01	0	4	0.00	0	0	-	1
	150g Top Deck	0	0	-	0	0	-	3	179	0.02	1	171	0.01	2	159	0.01	6
	235g Dairy Milk	0	0	-	0	0	-	0	0	-	0	0	-	4	0	-	4
	250g Black Forest	0	0	-	0	0	-	0	0	-	0	288	0.00	10	40	0.25	10
	250g Brazil Nut Milk	0	408	0.00	1	320	0.00	1	267	0.00	5	261	0.02	5	238	0.02	12
	250g Caramello	11	663	0.02	6	629	0.01	7	597	0.01	11	620	0.02	14	612	0.02	49
	250g Cashew Nut Milk	0	338	0.00	4	306	0.01	4	0	-	4	2	2.09	4	325	0.01	16
	250g Chocolate	8	0	-	3	0	-	0	0	-	0	0	-	0	0	-	11
	250g Chocolate Crackle	0	0	-	0	0	-	0	0	-	0	0	0.00	7	286	0.02	7
	250g Chocolate Ginger	0	0	-	0	0	-	2	0	-	0	0	-	0	0	-	2
	250g Chocolate Truffle	0	0	-	0	171	0.00	5	119	0.04	4	28	0.14	0	0	-	9
	250g Coconut Rough	0	0	-	0	0	-	0	0	-	1	179	0.01	0	95	0.00	1
	250g Crisp	1	291	0.00	0	244	0.00	1	190	0.01	1	210	0.00	1	178	0.01	4

APPENDIX I

Product Group	Product	1990			1991			1992			1993			1994			
		Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Total Complaints
	250g Dairy Milk	12	2744	0.00	16	2723	0.01	13	2470	0.01	9	2385	0.00	14	2360	0.01	64
	250g Energy	1	239	0.00	3	210	0.01	4	173	0.02	0	189	0.00	0	158	0.00	8
	250g English Toffee	5	226	0.02	3	121	0.02	0	0	-	0	0	-	0	0	-	8
	250g Fruit & Nut Milk	16	1092	0.01	25	1033	0.02	18	945	0.02	16	970	0.02	30	973	0.03	105
	250g Hazel Nut Milk	46	793	0.06	46	716	0.06	24	657	0.04	29	685	0.04	27	700	0.04	172
	250g Milky White	0	304	0.00	0	252	0.00	0	0	-	3	2	1.73	0	219	0.00	3
	250g Nut Mix	6	308	0.02	5	252	0.02	9	201	0.04	9	156	0.06	3	0	23.08	32
	250g Old Jamaica	7	430	0.02	10	382	0.03	9	367	0.02	0	396	0.00	3	386	0.01	29
	250g Peanut Brittle	0	0	-	0	0	-	0	0	-	0	0	0.00	6	261	0.02	6
	250g Peanut Milk	0	0	-	0	0	-	3	149	0.02	3	34	0.09	0	0	-	6
	250g Peppermint	8	435	0.02	8	434	0.02	5	405	0.01	10	451	0.02	3	462	0.01	34
	250g Plum Pudding	0	0	-	0	0	-	0	0	-	0	34	0.00	2	2	0.84	2
	250g Premium	1	137	0.01	1	100	0.01	0	127	0.00	2	158	0.01	0	154	0.00	4
	250g Roast Almond	10	616	0.02	7	547	0.01	7	485	0.01	7	536	0.01	8	585	0.01	39
	250g Rocky Road	0	0	-	0	0	-	3	238	0.01	12	157	0.08	12	156	0.08	27
	250g Snack	32	730	0.04	38	713	0.05	27	706	0.04	14	733	0.02	24	752	0.03	135
	250g Strawberry	3	69	0.04	3	17	0.18	0	0	-	0	0	-	0	0	-	6
	250g Swiss chalet	0	344	0.00	2	283	0.01	0	221	0.00	0	222	0.00	3	255	0.01	5
	250g Top Deck	1	653	0.00	0	625	0.00	4	595	0.01	1	687	0.00	2	680	0.00	8
	375g Caramello	1	46	0.02	0	28	0.00	0	0	-	0	0	-	0	0	-	1
	375g Dairy Milk	0	426	0.00	1	379	0.00	0	419	0.00	0	472	0.00	1	423	0.00	2
	375g Fruit & Nut Milk	10	183	0.05	4	153	0.03	3	165	0.02	0	181	0.00	2	184	0.01	22
	375g Hazel Nut Milk	18	169	0.11	5	134	0.04	7	142	0.05	8	157	0.05	8	175	0.05	46
	375g Roast Almond	6	78	0.08	4	50	0.08	0	45	0.00	0	0	0.00	0	0	-	10
	375g Snack	3	110	0.03	6	67	0.09	1	66	0.02	0	6	0.00	0	0	-	10
	50g Caramello	1	1	1.64	0	0	-	0	0	-	0	0	-	0	0	-	1
	50g Dairy Milk	2	0	-	0	0	-	0	0	-	0	0	-	0	0	-	2
	50g Fruit & Nut Milk	3	0	-	0	0	-	0	0	-	0	0	-	0	0	-	3
	50g Hazel Nut Milk	2	0	-	0	0	-	0	0	-	0	0	-	0	0	-	2
	50g Peppermint	0	0	-	1	0	-	0	0	-	0	0	-	0	0	-	1
	50g Snack	1	0	20.00	0	0	-	0	0	-	0	0	-	0	0	-	1

APPENDIX I

Product Group	Product	1990			1991			1992			1993			1994			
		Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Total Complaints
	50g Strawberry	1	0	-	0	0	-	0	0	-	0	0	-	0	0	-	1
	55g Caramello	0	153	0.00	9	146	0.06	2	143	0.01	3	143	0.02	4	128	0.03	18
	55g Caramello Roll	0	151	0.00	0	148	0.00	5	154	0.03	12	149	0.08	9	143	0.06	26
	55g Cashew Nut Milk	0	0	-	0	0	-	1	57	0.02	4	8	0.49	0	0	-	5
	55g Dairy Milk	8	523	0.02	7	514	0.01	8	563	0.01	10	569	0.02	4	530	0.01	37
	55g Dairy Milk Roll	0	409	0.00	0	427	0.00	8	459	0.02	9	407	0.02	11	372	0.03	28
	55g Fruit & Nut Milk	9	236	0.04	20	223	0.09	11	219	0.05	12	226	0.05	13	228	0.06	65
	55g Hazel Nut Milk	10	176	0.06	16	156	0.10	10	150	0.07	20	145	0.14	21	152	0.14	77
	55g Milky White	0	0	-	0	68	0.00	1	49	0.02	0	43	0.00	0	5	0.00	1
	55g Peppermint	7	116	0.06	11	107	0.10	7	108	0.06	6	111	0.05	8	108	0.07	39
	55g Peppermint Roll	0	115	0.00	0	118	0.00	7	127	0.06	11	120	0.09	11	122	0.09	29
	55g Roast Almond	13	111	0.12	7	85	0.08	6	75	0.08	8	79	0.10	10	87	0.11	44
	55g Snack	14	142	0.10	16	138	0.12	17	141	0.12	9	149	0.06	10	142	0.07	66
	55g Swiss Chalet	0	126	0.00	6	77	0.08	1	59	0.02	2	3	0.69	0	0	-	9
	55g Top Deck	0	169	0.00	1	149	0.01	1	144	0.01	0	148	0.00	0	144	0.00	2
	55g White Swiss Chalet	0	0	-	0	35	0.00	1	9	0.11	0	0	-	0	0	-	1
	75g Almond Nougat Lite	0	0	-	0	0	-	1	16	0.06	0	24	0.00	0	12	0.00	1
Moulded Total		356			348			289			344			377			1714
PIC'N'MIX	6.8kg Peanut Toffee	0	0	-	0	6	0.00	1	9	0.11	4	6	0.62	1	9	0.12	6
	6.8kg Turkish Delight	0	24	0.00	0	0	-	0	29	0.00	1	24	0.04	0	28	0.00	1
	6kg St Michaels Toffee	0	24	0.00	0	9	0.00	1	0	-	0	0	-	0	0	-	1
	6.8kg Choc Mint Fudge	1	9	0.11	0	5	0.00	0	10	0.00	0	6	0.00	0	7	0.00	1
	6.8kg Coffee Creams	1	13	0.08	0	5	0.00	0	12	0.00	0	10	0.00	0	11	0.00	1
	6.8kg Hazelnut Caramel	2	18	0.11	0	9	0.00	0	0	-	0	0	-	0	0	-	2
	6.8kg Peanut Brittle	7	8	0.86	1	4	-	0	0	-	0	0	-	0	0	-	8
	6.8kg Peppermint Creams	1	8	0.12	0	4	0.00	0	9	0.00	0	8	0.00	0	8	0.00	1
	6.8kg St. Michaels Caramel	1	7	0.14	0	5	0.00	0	0	-	0	0	-	0	0	-	1
	6.8kg Tropical Creams	1	8	0.13	0	5	0.00	0	8	0.00	0	6	0.00	0	8	0.00	1
	6.0 kg Hazelnut Caramel	0	0	-	0	9	0.00	0	20	0.00	0	17	0.00	1	21	0.05	1
Pic'n'mix Total		14			1			2			5			2			24
SELF	1.6kg After Dinner Mints	0	0	-	0	0	-	0	0	-	1	0	-	0	0	-	1

APPENDIX I

Product Group	Product	1990			1991			1992			1993			1994			
		Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Complaints	Sales(t)	Complaints /Sales(t)	Total Complaints
	250g Peppermint Cremes	0	49	0.00	0	28	0.00	3	11	0.26	0	0	-	1	0	-	4
	Peppermint Creme Disp.	1	132	0.01	2	96	0.02	1	128	0.01	1	122	0.01	3	103	0.03	8
Self Total		1			2			1			2			3			9
Grand Total		1727			1581			759			1018			874			5959

APPENDIX I

APPENDIX II

0	B	250G FRUIT & NUT
4 SQUARE, RIVER HILL SHOP	B	40G TOPS
7 day s/market stafford	B	15g FURRY FRIENDS
7/11 brighton le sands	B	15g FARM FRIENDS
727	B	250G HAZELNUT
727 Mee St Corina	B	55g TURKISH DELIGHT
ACTION, GIRRAWHEEN WA	B	30g FLAKE
Advantage Rockingham	B	55g HAZEL NUT MILK
ADVANTAGE SUPERMARKET, RO	B	250g HAZELNUT WHIRLS
ampol	B	250G HAZELNUT
ampol crest drummoyne	B	250G HAZELNUT
ampol richlands	B	150g HAZEL NUT MILK
Atkinson st	B	250G HAZELNUT
Ballajura City Deli	B	375g HAZEL NUT MILK
barner road wantirna	B	55g HAZEL NUT MILK
bi lo	B	250g ROSES
BI LO NORANDA	B	250G HAZELNUT
bi lo nth richmond	B	250g ROSES
BI LO THORNTON	B	250g ROSES
BI-LO, NORTH RICHMOND NSW	B	250g ROSES
BIG W	B	500g ROSES
big w	B	250g ROSES
big w.	B	250G ROCKY ROAD BLOCK
Big W	B	500g ROSES
big w	B	R/T 670G SCORCHED PEANUT
big w.	B	500g CONTINENTAL
Big w	B	250g DARK FAVOURITES
Big w	B	250g MILK TRAY
Big w	B	250g MILK TRAY
big w	B	250G FRUIT & NUT
big W	B	250g ROSES
big w	B	30g FLAKE
big w carindale	B	250g ROSES
BIG W - BOOVAL	B	200g TOFFEE POPS
BIG W - ERINA FAIR	B	C&B 250g DESSERT NOUGAT
big w belmont	B	250g DARK FAVOURITES
big w belmont	B	250g ROSES
BIG W BELMONT WWA	B	250G BOND STREET
big w blacktown	B	375g HAZEL NUT MILK
Big W Booral	B	250G HAZELNUT
big w browns plains	B	100G ROAST ALMOND P-PACK
BIG W CAMPBELLTOWN	B	250g ROSES
Big W Endeavour Hills	B	250g ROSES
big w frankston	B	250g MILK FAVOURITES
BIG W GLADSTONE	B	250g ROSES
big w gladstone	B	250g ROSES
big w gladstone	B	250g ROSES
big w gladstone	B	250g ROSES
big w gladstone	B	250g ROSES
big w highpoint s/centre	B	500g CONTINENTAL
big w ipswich	B	250g ROSES
BIG W KURABY QLD	B	250G BOND STREET
big w lavington	B	500g MILK TRAY
big w mackay	B	250G FRUIT & NUT
BIG W MIRANDA	B	375g HAZEL NUT MILK
BIG W MIRANDA	B	375g HAZEL NUT MILK
BIG W MIRANDA	B	250g ROSES
BIG W MIRANDA	B	250g ROSES
big w miranda fair sydney	B	250g ROSES
BIG W MIRRABOOKA	B	42G TWIRL
big w nth ryde	B	250g ROSES
big w penrith	B	250G BLACK FOREST BLOCK
big w penrith plaza	B	500g MILK TRAY
Big w Penruth	B	250g MILK TRAY
big w riverton	B	500g MILK TRAY
BIG W SOUTHLAND	B	250g ROSES

OUTLET DETAILS	COMP TYPE	PRODUCT
big w stafford	B	250g ROSES
big w stafford	B	250g ROSES
big w stafford	B	500g MILK TRAY
Big W Stafford	B	500g MILK TRAY
big w stafford city	B	250g ROSES
big w strathpine	B	250g ROSES
big w strathpine	B	250g ROSES
big w strathpine	B	250g ROSES
big w sunnybank	B	500g ROSES
BIG W TEE TRA PLAZA	B	500g MILK TRAY
big w ttp	B	250G HAZELNUT
big w Westfield strathpin	B	375g FRUIT & NUT MILK
Big w Whitfords	B	250g ROSES
big w whitfords shopping	B	250g MILK TRAY
Big W Whitfords Shopping	B	250g MILK TRAY
BIG W, AMBARVALE	B	250G HAZELNUT
BIG W, CAMPBELLTOWN	B	250g ROSES
BIG W, CAMPBELLTOWN NSW	B	250g ROSES
BIG W, EARLVILLE	B	250g ROSES
BIG W, ELIZABETH SA	B	250g ROSES
BIG W, GLADSTONE VIC	B	250g ROSES
BIG W, KIN KORA CENTRE, Q	B	250g ROSES
BIG W, KIN KORA CENTRE, Q	B	500g ROSES
BIG W, KINORA MALL, GLADS	B	375g HAZEL NUT MILK
BIG W, MACKAY QLD	B	500g MILK TRAY
BIG W, MIRRABOOKA WA	B	250g MILK TRAY
BIG W, MIRRABOOKA WA	B	250g MILK TRAY
BIG W, MIRRABOOKA WA	B	250g MILK TRAY
BIG W, MIRRABOOKA WA	B	250g MILK TRAY
BIG W, MIRRABOOKA WA	B	250g MILK TRAY
BIG W, MIRRABOOKA WA	B	250g MILK TRAY
BIG W, NSW	B	250G FRUIT & NUT
BIG W, NSW	B	250g ROSES
BIG W, PENRITH PLAZA, NSW	B	250g ROSES
BIG W, PHOENIX PARK WA	B	250g MILK FAVOURITES
BIG W, QLD	B	250G HAZELNUT
BIG W, QLD	B	250g ROSES
BIG W, ROCKHAMPTON	B	250g ROSES
BIG W, SOUTHLAND	B	250g ROSES
BIG W, STAFFORD CITY BRIS	B	500g MILK TRAY
BIG W, STAFFORD CITY, QLD	B	250g ROSES
bigw	B	250g MILK TRAY
bigW	B	250G BRAZIL NUT BLOCK
BIGW COFFS HARBOUR	B	250g ROSES
bigw srathpine	B	250g DARK FAVOURITES
bigw wetherill Park	B	250g ROSES
blackwood deli	B	55g DAIRY MILK ROLL
boylands	B	250g MILK TRAY
boylands s/market	B	250g MILK TRAY
bp foodstore port douglas	B	50g PICNIC
BP PENRITH NSW	B	55g CARAMELLO ROLL
BP S/STN, PADBURY	B	15g DAIRY MILK
BP SAINT PETERS	B	375g HAZEL NUT MILK
bp ss	B	BLACK FOREST 150G
bp Whitfords	B	BLACK FOREST 150G
bp williston	B	1.5kg PEPP. CREAM DISPENS
brownelea Towers bentley	B	30g FLAKE
Bunbury	B	500g MILK TRAY
byford liquor store byfor	B	250G BLACK FOREST BLOCK
caltex	B	150g TOP DECK
Caltex Rosewater	B	150g DAIRY MILK
CALTEX S/S, SYDNEY ROAD,	B	250G HAZELNUT
candlewood	B	250G ROAST ALMOND BLOCK
CANHAM WAY DELI GREENWOOD	B	100g FRUIT & NUT MILK P-P
Carina Kenrose street	B	55g TURKISH DELIGHT
CASH SALES RINGWOOD	B	250G DAIRY MILK
Charlie Carters	B	125g CADBURY COCOA
Cheap Foods Bedford	B	250G HAZELNUT
CHEAP FOODS, BELMONT WA	B	375g HAZEL NUT MILK
clancy sarATOGA	B	45g FRY's FIVE FRUITS
clancys Bradbury	B	250G CASHEW BLOCK
CLARKS FOODLAND BERRI	B	750g MILK TRAY
cnr 2nd + Ashton Ave	B	38G WISPA
cnr shop bronte road Wave	B	55g PEPPERMINT ROLL
COLES	B	250g MILK TRAY

OUTLET DETAILS	COMP TYPE	PRODUCT
coles	B	250G CHOCOLATE CRACKLE
coles	B	170G RT C SOLID CHOC MINI
coles	B	250g CONTINENTAL
Coles	B	250g ROSES
Coles	B	250g MILK FAVOURITES
coles	B	250g MILK FAVOURITES
Coles	B	250g MILK TRAY
coles	B	CRÈME EGG GIFT PACK
coles	B	CAPPUCCINO 110G
coles	B	250G HAZELNUT
coles	B	250g HAZELNUT WHIRLS
coles	B	250G HAZELNUT
coles	B	250G CHOCOLATE CRACKLE
coles	B	SWISS CHALET 100G P/P
COLES ALBANY CREEK QLD	B	250g ROSES
Coles Ayr	B	250g HAZELNUT WHIRLS
coles balcatta	B	375g HAZEL NUT MILK
COLES BALCATTA WA	B	55g HAZEL NUT MILK
Coles Forest Hills	B	30g FLAKE
COLES FOSSEY CLAREMONT	B	SNOWFLAKE 35G
coles Fremantle	B	250G ROAST ALMOND BLOCK
coles girrawheen	B	55g PEPPERMINT ROLL
coles girrawheen	B	250g MILK FAVOURITES
coles girrawheen	B	250g HAZELNUT WHIRLS
coles girrawheen	B	375g HAZEL NUT MILK
COLES GIRRAWHEEN WA	B	55g HAZEL NUT MILK
coles gosnells	B	30g FLAKE
coles ingle farm	B	C. HUMPTY DUMPTY 25G
coles innaloo	B	250g MILK TRAY
COLES KARATHA	B	FRUIT & NUT LOG 45G
coles kelmscott	B	100g HAZEL NUT MILK P-PAC
coles kelmscott	B	250G HAZELNUT
coles kelmscott	B	250G DAIRY MILK
Coles Maddington	B	250g DARK FAVOURITES
coles marangaroo	B	250g HAZELNUT WHIRLS
coles moranbah	B	250g MILK FAVOURITES
coles mosman park	B	FRUIT & NUT LOG 45G
coles northland	B	100g HAZEL NUT MILK P-PAC
Coles Northlands	B	55g PEPPERMINT ROLL
Coles Northlands Plaza	B	250G FRUIT & NUT
COLES PERTH WA	B	750g ROSES
Coles Phoenic Park & Sout	B	500g MILK TRAY
Coles Sunnybank	B	500g MILK TRAY
Coles Sunnybank hills	B	250g ROSES
coles toowong or w/w indo	B	HIDE N' SEEK 120G
coles warwick	B	40g CAD CARAMEL CREME EGG
coles Warwick	B	55g HAZEL NUT MILK
Coles Warwick	B	250g ROSES
coles warwick	B	250g ROSES
coles warwick	B	500g MILK TRAY
Coles West Ryde	B	MINI CREME EGGS 2KG
COLES, ARANA HILLS QLD	B	230G PICNIC BAG
COLES, CAPALABA	B	35g TWIRL (48)
COLES, CAULFIELD EAST	B	750g ROSES
COLES, GIRRAWHEEN WA	B	250g HAZELNUT WHIRLS
COLES, GLENROY	B	40G TOPS
COLES, HURSTVILLE	B	250g ROSES
COLES, INGLEWOOD WA	B	250g MILK TRAY
COLES, IPSWICH	B	500g MILK TRAY
COLES, KELMSCOTT WA	B	250g ROSES
COLES, MIRRABOOKA	B	250g MILK TRAY
COLES, MT PLEASANT WA	B	250g CONTINENTAL
COLES, NORANDA WA	B	50g PICNIC
COLES, ST MARYS NSW	B	200G CURLY WURLY
COLES, SUBIACO WA	B	375g DAIRY MILK
COLES, SUBIACO WA	B	55g PEPPERMINT
COLES, THORNLIE	B	55g SNACK
COLES, TOOMBUL	B	38G WISPA
collie coles	B	250g MILK FAVOURITES
COLMART, WESTLAND SHOPPIN	B	750g ROSES
confectionery w/house	B	AAW 130G CARNIVAL CASKET
corner store	B	OLD GOLD ROAST ALMOND 250
CPS CABOOLTURE QLD	B	55g HAZEL NUT MILK
cps mansfield	B	250G DAIRY MILK
Cut Price	B	250g MILK TRAY

OUTLET DETAILS	COMP TYPE	PRODUCT
CUT PRICE, MANSFIELD	B	250G DAIRY MILK
Ddgewater Deli	B	150g HAZEL NUT MILK
deli	B	55g FRUIT & NUT MILK
deli	B	250G CARAMELLO BLOCK
deli	B	150g PEPPERMINT
deli	B	250G BLACK FOREST BLOCK
Deli	B	150g FRUIT & NUT MILK
deli	B	30g FLAKE
deli	B	150g CARAMELLO
deli candlewood joondalu	B	250G FRUIT & NUT
Deli Carnarvon Street	B	250G HAZELNUT
Deli Cnr Albany &Kelvin R	B	150g ROAST ALMOND
deli cnr cocknan Canham w	B	CARAMELLO POCKET PACK 100
deli forrestlakes	B	250G CHOCOLATE CRACKLE
DELI IN MORLEY	B	250G CARAMELLO BLOCK
Deli Maylands	B	30g FLAKE
Deli on Bower Road	B	250G HAZELNUT
DELI ROCKINGHAM	B	250G FRUIT & NUT
Deli Scarborough bch rd M	B	55g FRUIT & NUT MILK
deli smith street	B	150g HAZEL NUT MILK
deli templeton drive	B	150g SNACK
deli vic park	B	55g CARAMELLO ROLL
deli white star forrestfi	B	45g FRY's CREAM
deli yangebup	B	50g PICNIC
DELI, ANZAC HIGHWAY	B	30g FLAKE
DELI, INGWOOD WA	B	150g SNACK
DELI, RAILWAY PDE, BECKEN	B	CARAMELLO POCKET PACK 100
DELI, WALTER RD, BEDFORD	B	250g MILK TRAY
DELI, WOODLANDS SHOPPING	B	CAPPUCCINO 110G
Eagle snack bar	B	OS MILK EGG 17G
Easterland Geelong	B	RT MOTOR CYCLE EGGS 50G
Easy Plus Subiaco	B	55g DAIRY MILK ROLL
esy plus	B	55g PEPPERMINT
express foodmart Hackham	B	150g FRUIT & NUT MILK
ezy plus	B	250G HAZELNUT
ezy plus Subiaco	B	250G CHOCOLATE CRACKLE
f/jacks	B	250G DAIRY MILK
farrant street stafford	B	15g FURRY FRIENDS
FESTIVAL FAIRE, WOOLWORTH	B	250g ROSES
FLEMINGS	B	250G FRUIT & NUT
Flemings	B	250G BLACK FOREST BLOCK
flemings nth sydney	B	250G CHOCOLATE CRACKLE
FLEMMING FOOD STORE, VICT	B	SWISS CHALET 100G P/P
Food Plus	B	13g CHUPA CHUPS
FOOD PLUS, CONDELL PARK	B	250g ROSES
FOOD PLUS, HOPPERS CROSSI	B	55g TURKISH DELIGHT
Foodland	B	500g MILK TRAY
Foodland	B	250G FRUIT & NUT
foodland athestone	B	250G HAZELNUT
foodland bayswater	B	55g FRUIT & NUT MILK
foodland bayswater	B	250g MILK TRAY
FOODLAND BEDFORD	B	40g TAKE 5
foodland Doubleview	B	250G HAZELNUT
Foodland doubleview	B	100g FRUIT & NUT MILK P-P
foodland kenwick	B	500g MILK TRAY
foodland kenwick	B	250g ROSES
foodland morphett vale	B	250g DRINKING CHOCOLATE
foodland mt hawthorn	B	250G HAZELNUT
FOODLAND, CASTLE PLAZA	B	6.0kg HAZELNUT CARAMEL
FOODLAND, LOVE ST, CLOVER	B	150g CARAMELLO
FOODLAND, SEVENTH ROAD, A	B	250g FRUIT & NUT MILK
Foodstore Eight Mile Plai	B	250G SNACK BLOCK
Foodstore Watland plaza	B	250G FRUIT & NUT
foodstore woodridge	B	250G HAZELNUT
FOODSTORE, WELLINGTON POI	B	DAIRY MILK AGRO 20G
fortitude valley foodstor	B	150g TOP DECK
FOUR SQUARE HOLLAND PARK	B	150g ROAST ALMOND
Franklins	B	250g MILK TRAY
Franklins	B	150G CARAMILK
franklins airport west	B	230G CHERRY RIPE BAG
franklins baulkham hills	B	500g MILK TRAY
FRANKLINS CHATSWOOD	B	250G FRUIT & NUT
franklins frenchs forest	B	375g HAZEL NUT MILK
franklins hillside	B	CAD 75G MILKY WHITE EGG
franklins leichhardt	B	CAPPUCCINO 110G

OUTLET DETAILS	COMP TYPE	PRODUCT
franklins lismore	B	55g DAIRY MILK ROLL
franklins loganholme	B	55g DAIRY MILK ROLL
Franklins Loganholne	B	55g DAIRY MILK ROLL
Franklins Mt. Gravatt	B	45g SUMMER ROLL
franklins strathpine	B	250g ROSES
FRANKLINS WENTWORTHVILLE	B	375g FRUIT & NUT MILK
Franklins Wentworthwille	B	250G BLACK FOREST BLOCK
FRANKLINS, BROOKSIDE	B	250g OLD GOLD
FRANKLINS, BUNDABERG	B	250g ROSES
FRANKLINS, LOGANHOLME	B	55g PEPPERMINT
FRANKLINS, MT. GRAVATT	B	250g MILK FAVOURITES
Fremantle Jetty	B	45g SUMMER ROLL
Fremantle kiosk	B	100G SNACK POCKET PACK
gangemis west perth	B	250G CHOCOLATE CRACKLE
general store	B	55g TURKISH DELIGHT
general store	B	180G SANTAS WORKSHOP
gift	B	250g MILK TRAY
gift	B	250g MILK TRAY
gift	B	250g ROSES
gift	B	500g ROSES
gift	B	300G RT LORETTA
gift	B	250g MILK FAVOURITES
gift	B	250g ROSES
gift	B	250g ROSES
GIFT, BIG W, WHITFORDS WA	B	CREME EGG GIFT PACK
GIFT, NSW	B	250g ROSES
GIFT, NSW	B	250g MILK TRAY
GIFT, NSW	B	250G BOND STREET
GIFT, NSW	B	250g MILK TRAY
GIFT, NSW	B	250g MILK TRAY
GIFT, QLD	B	250g DARK FAVOURITES
GIFT, QLD	B	250g ROSES
GIFT, QLD	B	250g MILK FAVOURITES
GIFT, QLD	B	250g ROSES
GIFT, QLD	B	250g ROSES
GIFT, QLD	B	250g ROSES
GIFT, SA	B	250g MILK TRAY
GIFT, VIC	B	250g MILK TRAY
GIFT, VIC	B	250g ROSES
GIFT, VIC	B	250g ROSES
GIFT, VIC	B	250g MILK TRAY
GIFT, WA	B	250g MILK TRAY
GIFT, WA	B	CAPPUCCINO 110G
GIFT, WA	B	ROSES 150G
Ginos recreation parlour	B	150g FRUIT & NUT MILK
girrawheen	B	100G SNACK POCKET PACK
Girrawheen Deli Summerfie	B	250G FRUIT & NUT
GLENFIELD NEWSAGENCY	B	15g DAIRY MILK
Glenrowan s/s	B	55g CARAMELLO ROLL
gorge rd deli athelstone	B	150g PEPPERMINT
green grocer chipping nor	B	250G CARAMELLO BLOCK
greenwood deli	B	250G CHOCOLATE CRACKLE
GREENWOOD KINGSLEY DELI.	B	250G ROAST ALMOND BLOCK
GREENWOOD SUPER DELI	B	250G CARAMELLO BLOCK
Hainsworth Plaza Deli	B	100G ROAST ALMOND P-PACK
HAMPTON ROAD, NEDLANDS WA	B	55g ROAST ALMOND
Hardey General	B	500g MILK TRAY
Hardy general store Hawth	B	250G PEANUT BRITTLE BLOCK
harrys mega deli armadale	B	15g DAIRY MILK
honesty shop box salvatio	B	55g SNACK
hot dog place richmond 77	B	38G WISPA
IGA FESTIVAL, GORDONVALE	B	ROSES 150G
island cnr store rockingh	B	250G PEPPERMINT BLOCK
island store Rockingham	B	150g SNACK
jewel bexley	B	250G CHOCOLATE CRACKLE
jewels	B	250g MILK TRAY
jewels kings langley	B	150g HAZEL NUT MILK
julia farr kiosk	B	250G HAZELNUT
k mart belmont	B	250G HAZELNUT
k mart casula	B	250g MILK TRAY
K MART CHATSWOOD	B	250g HAZELNUT WHIRLS
k mart cranebourne	B	250g ROSES
K MART NORLUNGA	B	500g ROSES
K MART SYLVANIA	B	750g MILK TRAY
k mart tirle	B	250G HAZELNUT

OUTLET DETAILS	COMP TYPE	PRODUCT
k mart west lakes	B	ROSES JAR 475G
K MART, CHARLESTOWN	B	250G CARAMELLO (OLD NO.)
K MART, MACKAY	B	5x15g FURRY FRIENDS
K MART, SHELLHARBOUR	B	250g ROSES
K-Mart	B	C CAD 40G CREME EGGS
K-Mart - Airport West	B	55g PEPPERMINT
K-MART, AIRLIE BEACH QLD	B	55g FRUIT & NUT MILK
K-MART, BELMONT WA	B	55g DAIRY MILK ROLL
K-MART, WARWICK WA	B	250g MILK TRAY
kd foodmarket dysart	B	ROSES 150G
Kellys snack bar	B	55g DAIRY MILK ROLL
KINGSGROVE ESTATE SHOP	B	55g PEPPERMINT
KMART FOOTSCRAY	B	250g MILK TRAY
KMART FOOTSCRAY	B	250g MILK TRAY
kmart footscray	B	250G MILK & DARK
KMART MT PLEASENT	B	250g HAZELNUT WHIRLS
KURRABA WHARF STORE	B	250G FRUIT & NUT
Lancel Plaza K Mart Bendi	B	50g PICNIC
langford deli	B	PEANUT BRITTLE 150G
lathlain deli	B	250G CHOCOLATE CRACKLE
LEWS DELI, BALLAJURA WA	B	150g CARAMELLO
lilydale market	B	150G MARILYNE BASKET
local deli	B	55g FRUIT & NUT MILK
LOCAL DELI, WA	B	150g ROAST ALMOND
Local Milk Bar Thompson S	B	250G CHOCOLATE CRACKLE
MADDINGTON VILLAGE DELI,	B	38G WISPA
Malibu Deli	B	250G ROAST ALMOND BLOCK
MANDURAH R/H	B	55g HAZEL NUT MILK
Manly West Foodlands	B	30g FLAKE
MANNING DELI, WA	B	250G SNACK BLOCK
marangaroo drive deli	B	55g PEPPERMINT ROLL
MARANGAROO DRIVE SUPA DEL	B	55g PEPPERMINT ROLL
MARANGAROO SUPER DELI, WA	B	45g FRY's CREAM
Marmion Village Pharmacy	B	55g HAZEL NUT MILK
matilda ipswich	B	CAPPUCCINO 110G
mc beth spearwood	B	250G FRUIT & NUT
MIDWAY GROCERY STORE	B	250G FRUIT & NUT
milk bar	B	250G ROAST ALMOND BLOCK
Milk Bar	B	55g CARAMELLO
MILK BAR HAWTHORN	B	250G PEANUT BRITTLE BLOCK
Milk Bar Aitkins st	B	100g HAZEL NUT MILK P-PAC
Milk Bar Atkinson Street	B	150g SNACK
milk bar bentleigh	B	55g FRUIT & NUT MILK
milk bar chadstone	B	100g HAZEL NUT MILK P-PAC
milk bar clovelly	B	250g MILK TRAY
milk bar ivanhoe west	B	250G FRUIT & NUT
milk bar keysborough	B	55g HAZEL NUT MILK
milk bar nth altona	B	55g HAZEL NUT MILK
Milk Bar Orial Road Melbo	B	55g CARAMELLO ROLL
MILK BAR RWD NTH SHOPPING	B	250G HAZELNUT
milk bar thomson st	B	150g FRUIT & NUT MILK
milk bar warrandyte road	B	250G CHOCOLATE CRACKLE
milk bar watsonia Rd wats	B	55g HAZEL NUT MILK
MILK BAR, 3 STEPS, STATIO	B	55g TURKISH DELIGHT
MILK BAR, ABBOTSFORD VIC	B	100g HAZEL NUT MILK P-PAC
MILK BAR, ALTONA	B	55g FRUIT & NUT MILK
MILK BAR, BLUFF ROAD, BLA	B	250G SNACK BLOCK
MILK BAR, CNR. ORIEL & BA	B	250G PEANUT BRITTLE BLOCK
MILK BAR, COLLINS PLACE,	B	250G FRUIT & NUT
MILK BAR, CRANBOURNE ROAD	B	250G DAIRY MILK
MILK BAR, DANDENONG VIC	B	250G CHOCOLATE CRACKLE
MILK BAR, DERBY ST, KENSI	B	150g CARAMELLO
MILK BAR, GLADSTONE PARK	B	250G HAZELNUT
MILK BAR, GRAND BOULEVARD	B	55g SNACK
MILK BAR, HUME HWY, BEVRI	B	30g FLAKE
MILK BAR, KOOYONG VIC	B	13g CHUPA CHUPS
MILK BAR, ROSEDALE	B	50G FRUIT PICNIC BAR
MILK BAR, THE BASIN VIC	B	250G HAZELNUT
MILK BAR, TULLAMARINE VIC	B	250G HAZELNUT
milkbar	B	250g MILK TRAY
milkbar cnr rathdowne st	B	250G TURKISH DELIGHT
milkbar keysborough corri	B	150g CARAMELLO
MILKSTORE, BURKE RD, GLEN	B	250G HAZELNUT
MINI MART, SCARBOROUGH BE	B	55g PEPPERMINT ROLL
mirrabooka	B	CAD SELECTION PACK

OUTLET DETAILS	COMP TYPE	PRODUCT
mobil Edensor park	B	55g HAZEL NUT MILK
mobil s/s beenliegh	B	150g SNACK
mobile beenliegh	B	150g SNACK
Morley Deli Cnr Wellingto	B	250g NUT MIX
mpc northmead	B	150g CARAMELLO
mt mt hawthorn supa deli	B	250G SWISS CHALET BLOCK
Narre Warren Milk Bar	B	55g CARAMELLO ROLL
Newmart Kardinya	B	FRUIT AND NUT BLOCK 400G
NEWMART, BALGA WA	B	80g CRUNCHIE
north quick serve	B	55g ROAST ALMOND
northam	B	250g ROSES
NORTHAM QUICK SERVICE, WA	B	150g TOP DECK
One Tree General Store	B	45g HONEY LOG
Parkerville General Store	B	250G CARAMELLO BLOCK
parkmore kmart	B	250g ROSES
payless maroubra	B	250G PEANUT BRITTLE BLOCK
payless maroubra	B	55g TOP DECK
PAYLESS, SUNBURY	B	50g PICNIC
pearl beach shop	B	250G PEANUT BRITTLE BLOCK
planet video mt lawley	B	42G TWIRL
q store	B	250G CHOCOLATE CRACKLE
quick serve northam	B	250G ROAST ALMOND BLOCK
Quick Stop Willagee	B	55g TURKISH DELIGHT
quick stop willagee	B	150g PEPPERMINT
QUICK STOP, COMO WA	B	MINI CREME EGGS 100G
QUIK STOP, COMO WA	B	250g HAZELNUT WHIRLS
Railway Parade Noble Park	B	55g ROAST ALMOND
Renown milk bar 337 Eliza	B	6.8kg PEANUT TOFFEE
RITE-WAY, ENMORE	B	55g SNACK
Riteway	B	30g FLAKE
Riteway Prahan	B	250G DAIRY MILK
River Hills 4 Square	B	250G FRUIT & NUT
Rockingham Seerwood	B	250G CARAMELLO BLOCK
ROSEBERRYS DELI, DIANELLA	B	55g FRUIT & NUT MILK
s/w eltham	B	250g DRINKING CHOCOLATE
s/w moonee ponds	B	250G SNACK BLOCK
s/w mornington	B	250g ROSES
s/w mornington	B	250g ROSES
s/w mulgrave	B	250G MILK & DARK
s/w wangaratta	B	140G CRUNCHIE NUGGET EGG
s/w wangaratta	B	C CAD 250G CRUNCHIE EGG
safeway eltham	B	CARAMEL EGG CARD 40G
SAFEWAY MILL PARK	B	42G TWIRL
SAFEWAY, MOONEE PONDS VIC	B	CRUNCHIE CARTON EGGS 230G
SAFEWAY, ROSEBUD	B	250g MILK TRAY
Sammys Milk Bar 83 Acland	B	250G ENERGY BLOCK
shell	B	150g HAZEL NUT MILK
shell hurstville	B	CHOC ECLAIRS 48G
SHELL MARKET CITY, CANNIN	B	140g CAD FRUIT & NUT EGG
SHELL SERVICE STATION, RI	B	55g PEPPERMINT
SHELL, CLAREMONT	B	55g CARAMELLO ROLL
SHELL, MARKET CITY, CANNI	B	95g CAD MILK FREDDO EGG
SNACK BAR	B	DAIRY MILK AGRO 20G
snack bar	B	55g CARAMELLO
Snake Valley General Stor	B	55g TURKISH DELIGHT
solo	B	250G FRUIT & NUT
Spicers Hamden rd Nedland	B	100g FRUIT & NUT MILK P-P
spicers nedlands	B	150g HAZEL NUT MILK
St Kilda Milk Bar Acland	B	250G SNACK BLOCK
sunnybank big w	B	250g ROSES
sunnybank big w	B	500g CONTINENTAL
sunnybank w/w	B	250g ROSES
SUPA DELI COCKBURN RD GRE	B	55g ROAST ALMOND
Supa Deli Girrawheen	B	250G HAZELNUT
supa deli morley	B	100G SNACK POCKET PACK
SUPA DELI, COCKMAN ROAD G	B	250G FRUIT & NUT
SUPA DELI, TEMPLETON CRST	B	55g CARAMELLO ROLL
Supa Snacks	B	50g CRUNCHIE
supa valu	B	250G HAZELNUT
supa valu	B	375g HAZEL NUT MILK
supa valu nedlands	B	250G HAZELNUT
Supa Valu Shenton Park	B	150g SNACK
supa valu stirling	B	500g ROSES
Supa Value Highgate	B	45g FRY's FIVE FRUITS
supa value stirling	B	250G HAZELNUT

OUTLET DETAILS	COMP TYPE	PRODUCT
supermarket maroubra	B	250G BLACK FOREST BLOCK
SUPERMARKET, ROMSEY VIC	B	250G DAIRY MILK
supr valu willagee	B	PEANUT BRITTLE 150G
TAFE shop	B	40g TAKE 5
TAKEAWAY, VICTORIA ROAD,	B	15g DAIRY MILK
target	B	250g ROSES
target	B	500g CONTINENTAL
target	B	250g HAZELNUT WHIRLS
target balga stirling gat	B	250g ROSES
target brookside	B	250g MILK TRAY
Target Browns Plains	B	250g ROSES
TARGET FREMANTLE	B	250g ROSES
target springwood	B	250g ROSES
TARGET WARRINGAH MALL NSW	B	200g ROSES LANTERN
TARGET, FREMANTLE	B	250g ROSES
TARGET, MEADOW FAIR, BROA	B	250g ROSES
TARGET, SOUTHPORT	B	250g ROSES
TARGET, SPRINGWOOD	B	ROSES 150G
THE VINES C'VAN PARK, WOO	B	55g PEPPERMINT ROLL
top shop narre warren	B	250G HAZELNUT
toys r us franklins	B	100G RT C TREASURE EGG
Vending	B	45G FRUIT BURST
vending	B	55g HAZEL NUT MILK
Vending Machine	B	50g PICNIC
vending machine	B	45G FRUIT BURST
VIDEO CONNECTION, MORLEY	B	250G CARAMELLO BLOCK
village store	B	100G ROAST ALMOND P-PACK
vulture street supermarke	B	55g TURKISH DELIGHT
w book exchange	B	55g DAIRY MILK ROLL
w/w	B	100g TINY FREDDO FROGS
w/w	B	250g ROSES
w/w	B	500g MILK TRAY
w/w	B	55g TURKISH DELIGHT
w/w	B	100g FRUIT & NUT MILK P-P
w/w arndale	B	250G CARAMELLO BLOCK
w/w belmont	B	250g MILK TRAY
w/w Bentley	B	250G SNACK BLOCK
w/w carindale	B	250g MILK TRAY
w/w centre point midland	B	250g MILK TRAY
w/w dampier	B	45g FRY's CREAM
w/w floreat	B	150g ROAST ALMOND
w/w floreat forum	B	250G DAIRY MILK
w/w grove plaza	B	30g FLAKE
w/w hervey bay	B	500g ROSES
w/w highpoint	B	250G DAIRY MILK
w/w inala	B	250g ROSES
w/w Karratha	B	250G HAZELNUT
w/w kempsey	B	250g HAZELNUT WHIRLS
w/w kuraby	B	500g ROSES
w/w maddington	B	100g FRUIT & NUT MILK P-P
w/w Maddington	B	250G PEANUT BRITTLE BLOCK
w/w miranda fair	B	CAD 75G PREMIUM DARK EGG
w/w Mt Druitt	B	55g DAIRY MILK
w/w neutral bay	B	500g MILK TRAY
w/w newman	B	250G BOND STREET
w/w Newman	B	DIPSTIX 55G
w/w pt lincoln	B	5x15g DAIRY MILK
w/w strathpine	B	50g CRUNCHIE
wangara caltex	B	250G CHOCOLATE CRACKLE
wanneroo deli	B	30g JUPITER
welcome mart	B	150g DAIRY MILK
Westfield Wpres Rd Westfi	B	150g DAIRY MILK
WHITE STAR DELI, SPEARWOO	B	250G PEPPERMINT BLOCK
whitfords	B	250g ROSES
whitfords big w	B	250g ROSES
Willetton Deli	B	150g HAZEL NUT MILK
WILLETTON DELI, WA	B	150g SNACK
woodside petroleum perth	B	15g DAIRY MILK
woolworths bullcreek	B	55g TURKISH DELIGHT
woolworths camden	B	250G ROAST ALMOND BLOCK
WOOLWORTHS DIANELLA WA	B	250G TOP DECK
WOOLWORTHS EASTWOOD	B	250g MILK TRAY
Woolworths Fairfield	B	250G HAZELNUT
WOOLWORTHS NSW	B	250g HAZELNUT WHIRLS
Woolworths Riverton	B	55g TURKISH DELIGHT

OUTLET DETAILS	COMP TYPE	PRODUCT
Woolworths Sydney Town Ha	B	250g ROSES
woolworths victor harbor	B	250G FRUIT & NUT
WOOLWORTHS WHITFORD WA	B	250g MILK TRAY
WOOLWORTHS, BENTLEY	B	250g HAZELNUT WHIRLS
WOOLWORTHS, CARINDALE	B	500g MILK TRAY
WOOLWORTHS, ENDEAVOUR HIL	B	250g ROSES
WOOLWORTHS, EPPING RD, MA	B	250g HAZELNUT WHIRLS
WOOLWORTHS, MORLEY	B	250g HAZELNUT WHIRLS
WOOLWORTHS, MORLEY WA	B	250G HAZELNUT
WOOLWORTHS, NEWMAN	B	55g SNACK
WOOLWORTHS, NEWMAN WA	B	250g ROSES
WOOLWORTHS, PORT AUGUSTA	B	500g ROSES
WOOLWORTHS, SUNNYBANK PLA	B	250g ROSES
WOOLWORTHS, WEATHERILL PA	B	50g PICNIC
WOOLWORTHS, WHITFORDS	B	250g MILK TRAY

APPENDIX III

Cadbury Schweppes

Cadbury Schweppes Pty Ltd ACN 004 551 473

23rd March 1995

Confectionery Division Price List

Your Confectionery Division Sales Executive's Name is.. Phone..........................

List No.	Description	Australian Prod. No.	Units per Outer	Outers per Container	Containers per Pallet (Base x Layer)	OUTER PRICING DETAILS: Recom-mended Wholesale List Price $	1000 or More Outers $	Ware-house & Redis-tribution $	RRP $
400g BLOCKS									
1884	DAIRY MILK	9300617318842	12	3	48(12x4)				
1885	FRUIT & NUT	9300617318859	12	3	48(12x4)	39.85	36.11	34.67	4.75
1886	HAZEL NUT	9300617318866	12	3	48(12x4)				
250g BLOCKS									
1161	DAIRY MILK	9300617311614	24	2	64(16x4)	57.04	51.69	49.62	3.40
1165	FRUIT & NUT	9300617311652	12	4	48(12x4)				
1182	SNACK	9300617311829	12	4	48(12x4)				
1181	CARAMELLO	9300617311812	12	4	48(12x4)				
1194	CARAMILK	9300617311942	12	4	64(16x4)				
1166	HAZEL NUT	9300617311669	12	4	48(12x4)				
1184	TOP DECK	9300617311843	12	4	48(12x4)				
1168	ROAST ALMOND	9300617311683	12	4	64(16x4)				
1183	PEPPERMINT	9300617311836	12	4	48(12x4)				
1167	BRAZIL NUT	9300617311676	12	4	64(16x4)				
1192	MILKY WHITE	9300617311928	12	4	64(16x4)				
1171	SWISS CHALET	9300617311713	12	4	64(16x4)	28.52	25.84	24.81	3.40
1170	CASHEW	9300617311706	12	4	64(16x4)				
1176	CHOCOLATE CRACKLE	9300617311768	12	4	48(12x4)				
1178	PEANUT BRITTLE	9300617311782	12	4	64(16x4)				
1174	BLACK FOREST	9300617311744	12	4	48(12x4)				
1185	LOONEY TUNES	9300617311850	12	4	60(15x4)				
1186	TURKISH DELIGHT	9300617311867	12	4	60(15x4)				
1195	OLD GOLD DARK CHOCOLATE	9300617311959	12	4	64(16x4)				
1196	OLD GOLD OLD JAMAICA	9300617311966	12	4	64(16x4)				
1197	OLD GOLD ENERGY	9300617311973	12	4	64(16x4)				
1198	OLD GOLD ROAST ALMOND	9300617311980	12	4	64(16x4)				
150g BLOCKS									
1011	DAIRY MILK	9300617310112	24	3	80(16x5)	36.91	33.45	32.11	2.20
1038	FRUIT & NUT	9300617310389	12	6	65(13x5)				
1068	SNACK	9300617310686	12	6	60(12x5)				
1070	CARAMELLO	9300617310709	12	6	60(12x5)				
1035	CARAMILK	9300617310358	12	6	80(16x5)				
1036	HAZEL NUT	9300617310365	12	6	65(13x5)				
1043	TOP DECK	9300617310433	12	6	60(12x5)				
1037	ROAST ALMOND	9300617310372	12	6	60(12x5)	18.46	16.73	16.06	2.20
1069	PEPPERMINT	9300617310693	12	6	60(12x5)				
1045	MILKY WHITE	9300617310457	12	6	80(16x5)				
1050	CHOCOLATE CRACKLE	9300617310501	12	6	65(13x5)				
1060	PEANUT BRITTLE	9300617310600	12	6	65(13x5)				
1049	BLACK FOREST	9300617310495	12	6	65(13x5)				
1034	TURKISH DELIGHT	9300617310341	12	6	60(12x5)				
1033	OLD GOLD OLD JAMAICA	9300617310334	12	6	65(13x5)				

CHOCOLATE GROUP

List No.	Description	Australian Prod. No.	Units per Outer	Outers per Container	Containers per Pallet (Base x Layer)	OUTER PRICING DETAILS: Recommended Wholesale List Price $	1000 or More Outers $	Warehouse & Redistribution $	RRP $
100g BLOCKS									
1061	GOLD CARAMEL	9300617310617	12	8	72(12x6)				
1062	GOLD CHOCOLATE	9300617310624	12	8	72(12x6)	20.97	19.00	18.24	2.50
1863	GOLD HAZEL NUT	9300617310631	12	8	72(12x6)				
100g POCKET PACKS									
1461	DAIRY MILK	9300617314615	24	4	64(16x4)				
1470	SNACK	9300617314707	24	4	64(16x4)				
1462	FRUIT & NUT	9300617314622	24	4	64(16x4)				
1463	HAZEL NUT	9300617314639	24	4	64(16x4)				
1464	ROAST ALMOND	9300617314646	24	4	64(16x4)	27.68	25.08	24.08	1.65
1468	SWISS CHALET	9300617314684	24	4	64(16x4)				
1466	CARAMELLO	9300617314660	24	4	64(16x4)				
1467	TOP DECK	9300617314677	24	4	64(16x4)				
1471	PEPPERMINT	9300617314714	24	4	64(16x4)				
1473	CARAMILK	9300617314738	24	4	64(16x4)				
75g BLOCKS									
1051	MILK LITE	9300617310518	12	12	60(10x6)				
1053	HAZEL NUT LITE	9300617310532	12	12	60(10x6)	13.42	12.17	11.68	1.60
1054	ALMOND NOUGAT LITE	9300617310549	12	12	60(10x6)				
55g BLOCKS									
2012	DAIRY MILK	9300617320128	36	6	48(16x3)				
2013	FRUIT & NUT	9300617320135	36	6	48(16x3)				
2024	CARAMILK	9300617320241	36	6	48(16x3)				
2014	HAZEL NUT	9300617320142	36	6	48(16x3)				
2015	ROAST ALMOND	9300617320159	36	6	48(16x3)	23.91	21.67	20.80	.95
2016	CARAMELLO	9300617320166	36	6	48(16x3)				
2017	SNACK	9300617320173	36	6	48(16x3)				
2018	PEPPERMINT	9300617320180	36	6	48(16x3)				
2019	TOP DECK	9300617320197	36	6	48(16x3)				
55g ROLLS									
2031	DAIRY MILK	9300617320319	36	6	60(10x6)				
2032	CARAMELLO	9300617320326	36	6	60(10x6)	23.91	21.67	20.80	.95
2033	PEPPERMINT	9300617320333	36	6	60(10x6)				
SHARE PACK - MOULDED									
4151	235g DAIRY MILK	9300617341512	24	1	60(12x5)				
4154	235g HAZEL NUT	9300617341543	24	1	60(12x5)				
4155	235g FRUIT & NUT	9300617341550	24	1	60(12x5)	61.62	55.84	53.61	3.45
4156	235g TOP DECK	9300617341567	24	1	48(12x4)				
4157	235g CARAMILK	9300617341574	12	1	96(16x6)	30.81	27.92	26.80	3.45
SHARE PACK - BARS									
4162	230g CHERRY RIPE	9300617341628	24	1	60(12x5)				
4165	230g PICNIC	9300617341659	24	1	40(10x4)				
4163	230g CRUNCHIE	9300617341635	24	1	32(8x4)	61.62	55.84	53.61	3.45
4166	160g TWIRL	9300617341666	24	1	36(9x4)				
6041	180g TAKE 5	9300617360414	24	1	40(10x4)				
4169	250g NUDGE	9300617341697	24	1	60(12x5)	30.81	27.92	26.80	3.45
4174	200g TIME OUT	9300617341741	12	1	32 (8x4)	30.81	27.92	26.80	3.45
SHARE PACK - CHILDREN'S									
4256	240g DAIRY MILK FREDDO	9300617342564	24	1	40(10x4)				
4265	240g CARAMELLO KOALA	9300617342656	24	1	60(12x4)				
4257	240g MILK WHITE FREDDO	9300617342571	24	1	40(10x4)				
4260	240g MILKY TOP FREDDO	9300617342601	24	1	40(10x4)	61.62	55.84	53.61	3.45
4266	220g AGRO	9300617342663	24	1	60(12x5)				
4267	220g AGRO CRANKY CRISP	9300617342670	24	1	60(12x5)				
4164	235g CHOMP	9300617341642	24	1	32(8x4)				
4261	240g STRAWBERRY FREDDO	9300617342618	12	1	96(16x6)				
8900	200g CURLY WURLY	9400550689006	12	1	70(10x7)	30.81	27.92	26.80	3.45
4268	220g LOONEY TUNES	9300617342687	12	1	70(10x5)				
BREAK PACK									
2767	150g TIME OUT	9300617327875	12	1	168 (24X7)	23.47	21.27	20.42	2.70

CHOCOLATE GROUP

List No.	Description	Australian Prod. No.	Units per Outer	Outers per Container	Containers per Pallet (Base x Layer)	OUTER PRICING DETAILS Recom-mended Wholesale List Price $	1000 or More Outers $	Ware-house & Redis-tribution $	RRP $
SNACK PACK - CHILDREN'S									
1614	5 PK FURRY FRIENDS	9300617316145	48	1	160(32x5)				
3052	5 PK DAIRY MILK	9300617330523	48	1	160(32x5)	58.72	53.22	51.09	1.75
3272	5 PK M/WHITE FARM/F	9300617332725	48	1	160(32x5)				
LARGE BARS									
2419	85g CHERRY RIPE	9300617324195	36	4	48(12x4)	31.46	28.51	27.37	1.25
2406	80g CRUNCHIE	9300617324065	24	3	52(13x4)	20.97	19.00	18.24	1.25
2581	70g TWIRL 4 FINGER	9300617325819	24	6	32(8x4)	30.20	27.36	26.27	1.80
MEDIUM BARS									
2574	55g CHERRY RIPE	9300617325741	48	4	50(10x5)	31.88	28.90	27.74	.95
2286	50g CRUNCHIE	9300617322863	42	6	20(10x2)	27.89	25.27	24.26	.95
2354	50g PICNIC	9300617323549	48	4	32(8x4)	31.88	28.90	27.74	.95
2572	42g TWIRL	9300617325727	48	6	32(8x4)	31.88	28.90	27.74	.95
2503	30g FLAKE	93617406	50	9	30(10x3)	33.21	30.09	28.89	.95
3573	55g TURKISH DELIGHT	9300617335733	50	4	64(16x4)	33.21	30.09	28.89	.95
2530	50g NUDGE	9300617325307	36	4	63(9x7)	23.91	21.67	20.80	.95
2765	45g FRY'S CREAM	9300617327653	48	6	48(16x3)				
1643	45g FRY'S 5 FRUITS	9300617316435	48	6	48(16x3)	31.88	28.90	27.74	.95
2578	40g TAKE 5	9300617325789	48	4	36(12x3)				
2526	40g ROCKY ROAD RUNNER	9300617325260	42	6	39(13x3)	17.62	15.97	15.33	.60
2507	40g TIME OUT	9300617325079	48	6	32 (8x4)	31.88	28.90	27.74	.95
2372	65g WHIP	9300617323723	30	6	45(15x3)	16.78	15.21	14.60	.80
SMALL BARS									
10063	30g PEPPERMINT TRUFFLE*	————	48	6	78(12x6)	15.10	13.69	13.14	.45
2341	30g CHOMP	9300617323419	50	6	32(8x4)	15.73	14.26	13.69	.45
2493	30g PEPPERMINT CHOMP	9300617324935	50	6	32(8x4)				
ASSORTMENTS									
04226	250g MILK FAVOURITES	9300616042267	6	8	24(8x3)	32.43	29.39	28.21	8.00
04227	250g DARK FAVOURITES	9300616042274	6	8	24(8x3)				
3801	250g CABARET	9300616338018	6	6	30(10x3)	24.12	21.85	20.98	5.95
3851	125g AFTER DINNER MINTS	9300616338513	12	6	30(10x3)	33.24	30.13	28.92	4.10
3852	250g AFTER DINNER MINTS	9300616338520	6	6	30(10x3)	27.77	25.17	24.16	6.85
04225	200g LIQUEUR CHERRIES	9300616042250	6	6	24(12x2)	42.36	38.39	36.85	10.45
04230	250g FRUIT JELLIES	9300616042304	6	6	39(13x3)	27.77	25.17	24.16	6.85
3531	250g MILK TRAY	9300617335313	6	8	24(8x3)	32.43	29.39	28.21	8.00
3544	500g MILK TRAY	9300617335443	3	6	24(8x3)	30.91	28.01	26.89	15.25
3557	750g MILK TRAY	9300617335573	2	6	36(12x3)	30. 34	27.50	26.40	22.45
3847	150g ROSES	9300617338475	6	12	27(9x3)	15.81	14.32	13.75	3.90
3566	250g ROSES	9300617335665	6	8	24(6x4)	27.36	24.79	23.80	6.75
3567	500g ROSES	9300617335672	3	8	24(8x3)	25.95	23.52	22.58	12.80
3902	500g ROSES SQUARE TIN	9300617339021	3	4	30(10x3)	32.64	29.58	28.40	16.10
3832	750g ROSES	9300617338321	2	6	32(8x4)	25.68	23.27	22.34	19.00
3749	250g BLACK CAT	9300617337492	6	8	24(8x3)				
7028	250g CONTINENTAL	9400550002911	6	6	27(9x3)	32.43	29.39	28.21	8.00
4145	500g CONTINENTAL	9400550002935	3	6	27(9x3)	30.91	28.01	26.89	15.25
3793	250g HAZEL NUT WHIRLS	9300617337935	6	8	24(8x30	33.24	30.13	28.92	8.20
8901	250g TRAD MILK/DARK	9400550689013	3	4	52(13x4)	22.20	20.11	19.31	10.95
7049	500g BOND STREET LANTERN	9400550669541	4	4	40(8x5)	32.43	29.39	28.21	12.00
8902	110g CAPPUCCINO	9400550689020	12	6	45(9x5)	32.03	29.03	27.87	3.95
8303	250g CAPPUCCINO	9400550689037	6	6	36(12x3)	32.32	29.29	28.12	7.95

CHOCOLATE GROUP

Containers per Pallet (Base x Layer)

Outers per Container

Units per Outer

List No.	Description	Australian Prod. No.	Units per Outer	Outers per Container	Containers per Pallet (Base x Layer)	OUTER PRICING DETAILS: Recom-mended Wholesale List Price $	1000 or More Outers $	Ware-house & Redis-tribution $	RRP $
SELF LINES									
4296	50g CRUNCHIE NUGGETS	9300617342960	36	8	16(8x2)	22.65	20.53	19.71	.90
4297	185g CRUNCHIE NUGGETS	9300617342977	24	—	80(16x5)	47.33	42.90	41.18	2.65
3492	PEPP. CREAM DISP.	9300617334927	100	6	64(16x4)	14.11	12.79	12.28	.20
CHILDREN'S LINES									
3221	MILK FREDDO	93617062	108	4	60(15x4)	18.88	17.11	16.43	.25
3120	CARAMELLO KOALA	93617482	72	6	40(10x4)	17.62	15.97	15.33	.35
3222	MILKY WHITE FREDDO	93617079	108	4	60(15x4)	18.88	17.11	16.43	.25
3230	RAINBOW CHIP FREDDO	93617086	72	6	40(10x4)	17.62	15.97	15.33	.35
3223	12g MILKY TOP FREDDO	93685634	108	4	60(15x4)	18.88	17.11	16.43	.25
3298	STRAWBERRY FREDDO	93617475	72	6	40(10x4)				
3311	PEPPERMINT FREDDO	93617468	72	6	40(10x4)				
3231	HONEYCOMB FREDDO	93685757	72	6	40(10x4)				
1591	FURRY FRIENDS	93685535	72	9	60(12x5)	17.62	15.97	15.33	.35
3133	DAIRY MILK	93685542	72	9	60(12x5)				
3269	MILKY WHITE FARM FR.	93685559	72	9	60(12x5)				
3139	15g CARAMILK	93685665	72	9	60(12x5)				
3324	TWIN FREDDO	93685573	36	6	36(12x3)	17.62	15.97	15.33	.70
3146	CAR. KOALA TWIN	93617215	36	6	36(12x3)				
3211	CURLY WURLY BAR	9400550002485	48	6	48(12x4)	13.54	12.27	11.78	.40
3136	AGRO	93617413	72	6	40(10x4)				
3137	AGRO CRANKY CRISP	93685528	72	6	40(10x4)	17.62	15.97	15.33	.35
3138	20g LOONEY TUNES	93685658	76	6	40(10x4)				
3337	GIANT FREDDO	9300617333371	36	6	52(13x4)	17.62	15.97	15.33	.70
3338	GIANT KOALA	9300617333388	36	6	50(10x5)				
3340	100g TINY FREDDO	9300617333401	24	4	27(9x3)	33.56	30.42	29.20	2.00
PICK 'N' MIX									
WRAPPED BULK									
5410	6.8kg ASSORTED JELLIES	9300617354109	1	1	72(12x6)	46.13	41.80	40.13	10.05
5411	6.8kg PEPPERMINT TRUFFLE	9300617354116	1	1	72(12x6)	69.55	63.03	60.51	15.15
5412	6.8kg COCONUT ROYALS	9300617354123	1	1	72(12x6)	64.91	58.82	56.47	14.15
5413	6.8kg TURKISH DELIGHT	9300617354130	1	1	72(12x6)				
5414	6.8kg RUM TRUFFLE	9300617354147	1	1	72(12x6)	72.33	65.55	62.93	15.75
5415	6.8kg ENGLISH FUDGE	9300617354154	1	1	72(12x6)	85.09	77.11	74.03	15.75
5417	6.8kg CHOC. MINT FUDGE	9300617354178	1	1	72(12x6)	72.33	65.55	62.93	15.75
5418	6.8kg RASPBERRY CREAM	9300617354185	1	1	72(12x6)				
5419	6.8kg STRAWBERRY CREAM	9300617354192	1	1	72(12x6)	80.67	73.10	70.18	17.55
5420	6.8kg TROPICAL CREAMS	9300617354208	1	1	72(12x6)				
5421	6.8kg PEANUT TOFFEE	9300617354215	1	1	72(12x6)	81.83	74.16	71.19	17.80
5422	6.8kg ORANGE CREAMS	9300617354222	1	1	72(12x6)				
5423	6.8kg HAWAIIAN CARAMEL	9300617354239	1	1	72(12x6)	80.67	73.10	70.18	17.55
5424	6.8kg COFFEE CREAMS	9300617354246	1	1	72(12x6)				
5425	6.8kg GINGER JELLY	9300617354253	1	1	72(12x6)	104.78	94.96	91.16	22.80
5426	6.8kg PEPPERMINT CREAM	9300617354260	1	1	72(12x6)	101.07	91.59	87.93	22.00
5427	6.0kg ST. MICHAEL CARAMEL	9300617354277	1	1	72(12x6)	89.18	80.82	77.59	22.00
5428	6.0kg CHERRY MACAROONS	9300617354284	1	1	72(12x6)	94.43	82.85	79.54	22.55
5430	6.8kg FRENCH NOUGAT	9300617354307	1	1	72(12x6)	104.78	94.96	91.16	22.80
5431	6.0kg HAZEL NUT CARAMEL	9300617354314	1	1	72(12x6)	92.45	83.78	80.43	22.80
11326	2.2kg LIQUEUR CHERRIES	9300616113264	1	4	40(8x5)	51.23	46.43	44.57	34.45
UNWRAPPED BULK									
5451	2.6kg DOUBLE DIPS	9300617354512	1	1	224(28x8)	22.16	20.08	19.28	12.60
5441	3.0kg SCORCHED PEANUTS	9300617354413	1	1	224(28x8)	24.24	21.97	21.09	11.95
5442	2.1kg CHOC. ANISEED RINGS	9300617354420	1	1	224(28x8)	18.69	16.94	16.26	13.15
5449	3.5kg BULLETS	9300617354499	1	1	224(28X8)	35.80	32.45	31.15	15.15
5450	3.0kg SCORCHED ALMONDS	9300617354505	1	1	224(28x8)	36.92	33.46	32.12	18.20

CHOCOLATE GROUP

List No.	Description	Australian Prod. No.	Units per Outer	Outers per Container	Containers per Pallet (Base x Layer)	Recommended Wholesale List Price $	1000 or More Outers $	Warehouse & Redistribution $	RRP $
FOOD PRODUCTS									
CADBURY									
6606	125g COCOA #	9300617366065	24	1	140(28x5)	33.56	30.42	29.20	1.54
6619	250g COCOA#	9300617366195	24	1	72(18x4)	63.41	57.47	55.17	2.91
6622	375g COCOA#	9300617366225	12	1	100(20x5)	46.31	41.97	40.29	4.25
6680	250g DRINKING CHOC. #	9300617366805	24	1	96(16x6)	32.69	29.63	28.44	1.50
6693	500g DRINKING CHOC. #	9300617366935	12	1	100(20x5)	31.16	28.24	27.11	2.86
1218	250g DARK COOKING CHOC. #	9300617312185	12	4	60(15x4)	28.52	25.84	24.81	2.62
1219	250g MILK COOKING CHOC. #	9300617312192	12	4	60(15x4)				
UNICHOC									
6651	300g DARK COOKING CHOC. #	9300617366515	12	2	90(30x3)	18.75	16.99	16.31	1.72
6664	300g MILK COOKING CHOC. #	9300617366645	12	2	90(30x3)				
BISCUITS									
6716	150g CHOCOLATE WAFER	9300617367161	20	1	144(24x6)	33.39	30.26	29.05	2.00
6745	200g TOFFEE POPS	9300617367451	20	1	96(24x4)				
6758	200g CHOCOLATE DOUBLES	9300617367581	20	1	96(16x6)				
6761	200g MINT CREAMS	9300617367611	20	1	96(24x4)				
6787	200g ZOO ANIMALS	9200617367871	20	1	60(12x5)				
6800	200g CHOCOLATE FINGERS	9200617368007	20	1	80(16x5)				
6813	200g SQUIGGLE TOPS	9300617368137	20	1	56(14x4)				
6788	200g RAINBOWS	9300617367888	20	1	64(16x4)				

APPENDIX IV

Cadbury Schweppes Sales Executive Reimbursement Policy

Product Group	**Serious complaint (Infestation)**
Assortments	2 x complaint product plus 2 x Multibags or Blocks
Moulded Self Food	1 x 250g Milk Tray or Favourites plus 2 x complaint product
Children's	1 x 250g Milk Tray or Favourites plus 1 Multibag of complaint product
Bars	1 x 250g Milk Tray or Favourites plus 4 x complaint product

APPENDIX V

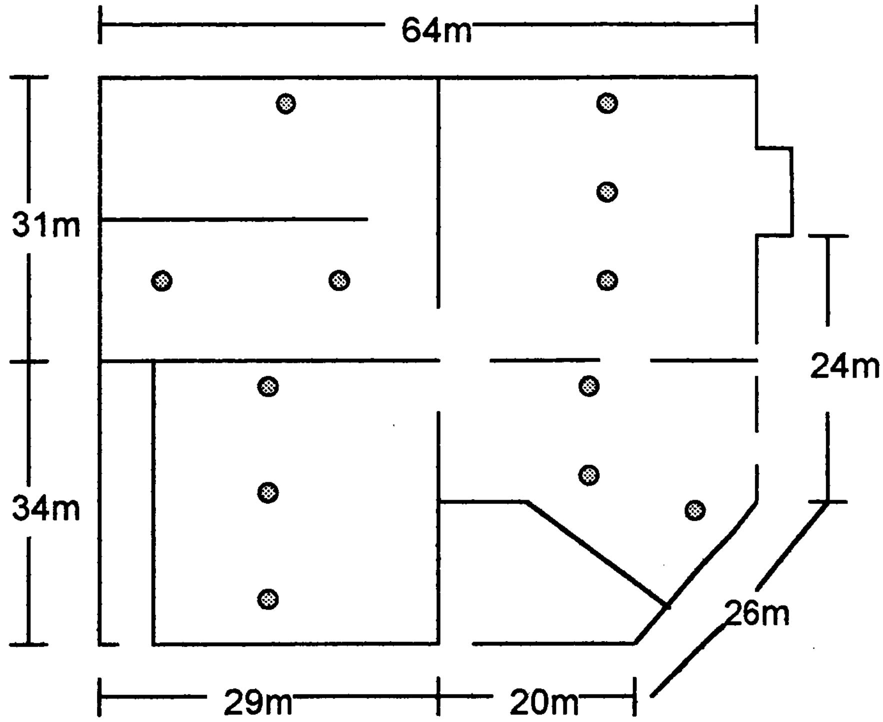
Product group	Product	Customer district	Customer state	Retail outlet district	Retail outlet state	Nut ingredient	Pest type	Identification
Assortments	120g Roses Easter Egg	Sumerset Dam	QLD			+	Lepidoptera	
	150g Roses	Gordonvale	QLD	Gordonvale	QLD	+	Lepidoptera	
	150g Roses					+	Lepidoptera	
	200g Liquer Cherries	Salter Pt.	WA			-	Lepidoptera	*Plodia interpunctella*
	200g Roses	Hilton	WA			+	Lepidoptera	*Plodia interpunctella*
	200g Roses	Williamstown	VIC			+	Lepidoptera	
	250g Hazelnut Whirls	Alfred Cove	WA			+	Lepidoptera	*Plodia interpunctella*
	250g Hazelnut Whirls	Balgownie	NSW			+	Lepidoptera	
	250g Hazelnut Whirls	Chifley	NSW			+	Lepidoptera	
	250g Hazelnut Whirls	Daisy Hill	QLD	Woodridge	QLD	+	Lepidoptera	*Plodia interpunctella*
	250g Hazelnut Whirls	Dianella	VIC			+	Lepidoptera	
	250g Hazelnut Whirls	Drake	NSW			+	Lepidoptera	
	250g Hazelnut Whirls	Mackay	QLD	Mt Pleasant	QLD	+	Lepidoptera	
	250g Hazelnut Whirls	Matraville	NSW			+	Lepidoptera	*Plodia interpunctella*
	250g Hazelnut Whirls	Neutral Bay	NSW	Chatswood	NSW	+	Lepidoptera	
	250g Hazelnut Whirls	Rockhampton	QLD			+	Lepidoptera	*Plodia interpunctella*
	250g Hazelnut Whirls	Rockingham	WA			+	Lepidoptera	*Plodia interpunctella*
	250g Hazelnut Whirls	Sanctuary Pt	NSW	Nowra	NSW	+	Lepidoptera	
	250g Hazelnut Whirls		NSW	Miranda	NSW	+	Lepidoptera	*Plodia interpunctella*
	250g Hazelnut Whirls		WA	Rockingham	WA	+	Lepidoptera	
	250g Milk Favourites	Castlehill	NSW			+	Lepidoptera	*Ephestia kuhniella*
	250g Milk Favourites	Millswood	SA			+	Lepidoptera	
	250g Milk Tray	Attadale	WA			+	Lepidoptera	
	250g Milk Tray	Belmont	VIC			+	Lepidoptera	
	250g Milk Tray	Bli Bli	QLD			+	Coleoptera	*Oryzaephilus surinamensis*
	250g Milk Tray	Bundell	QLD			+	Lepidoptera	
	250g Milk Tray	Chatswood	NSW	Gordon	NSW	+	Lepidoptera	*Ephestia cautella*
	250g Milk Tray	Como	WA			+	Lepidoptera	
	250g Milk Tray	Dural	NSW	Eastwood	NSW	+	Lepidoptera	
	250g Milk Tray	Hammersley	WA			+	Lepidoptera	
	250g Milk Tray	Holsworthy	NSW	Casula	NSW	+	Lepidoptera	
	250g Milk Tray	Kyabram	VIC			+	unknown	
	250g Milk Tray	Lake Heights	NSW	Lake Heights	NSW	+	Lepidoptera	
	250g Milk Tray	McGraths Hill	NSW			+	Lepidoptera	*Ephestia kuhniella*
	250g Milk Tray	Nth Ryde	NSW	Erina	NSW	+	Lepidoptera	*Ephestia elutella*
	250g Milk Tray	Reynella	NSW			+	Lepidoptera	
	250g Milk Tray	Sunny Bank	QLD	Sunny Bank	QLD	+	Lepidoptera	
	250g Milk Tray	Tuart Hill	WA			+	Lepidoptera	
	250g Milk Tray	Unaderra	NSW			+	Lepidoptera	
	250g Milk Tray	Whitegum Valley	WA	Kardinya	WA	+	Lepidoptera	
	250g Milk Tray		QLD			+	Lepidoptera	
	250g Milk Tray					+	Lepidoptera	
	250g Milk Tray					+	Lepidoptera	
	250g Milk Tray					+	Lepidoptera	
	250g Roses	Balarang	NSW	Shell Harbour	NSW	+	Lepidoptera	
	250g Roses	Balcutta	WA			+	Lepidoptera	
	250g Roses	Biggenden	QLD			+	Lepidoptera	
	250g Roses	Boronia Heights	QLD			+	Lepidoptera	
	250g Roses	Buderim	QLD	Buderim	QLD	+	Lepidoptera	
	250g Roses	Chelsea Heights	VIC			+	Lepidoptera	*Ephestia cautella*
	250g Roses	Condell Park	NSW			+	Lepidoptera	
	250g Roses	Cranbourne	VIC			+	Lepidoptera	*Ephestia elutella*
	250g Roses	Cranbourne Nth	VIC			+	Lepidoptera	*Ephestia figulilella*
	250g Roses	Dubbo	NSW			+	Lepidoptera	
	250g Roses	Eumamo	QLD			+	Lepidoptera	
	250g Roses	Everton Hills	QLD			+	Lepidoptera	
	250g Roses	Ferny Grove	QLD	Stafford	QLD	+	Lepidoptera	
	250g Roses	Gladstone	QLD			+	Lepidoptera	
	250g Roses	Grovely	QLD			+	Lepidoptera	*Plodia interpunctella*
	250g Roses	Ipswich	QLD	Ipswich	QLD	+	Lepidoptera	*Ephestia cautella*
	250g Roses	Marion	QLD			+	Lepidoptera	
	250g Roses	Marsfield	NSW	Nth Ryde	NSW	+	Lepidoptera	*Ephestia cautella*
	250g Roses	Miranda	NSW			+	Lepidoptera	*Ephestia cautella*
	250g Roses	Newman	WA	Newman	WA	+	Lepidoptera	*Plodia interpunctella*
	250g Roses	Nth Epping	NSW	Nth Ryde	NSW	+	Lepidoptera	
	250g Roses	Oxley	QLD	Sunny Bank	QLD	+	Lepidoptera	*Paralipsa gularis*
	250g Roses	Pacific Paradise	QLD	Kawana Waters	QLD	+	Lepidoptera	*Ephestia cautella*
	250g Roses	Sth Perth	WA			+	Lepidoptera	
	250g Roses	Stirling	WA			+	Lepidoptera	
	250g Roses	Sunny Bank Hills	QLD			+	Lepidoptera	
	250g Roses	Warana	QLD			+	Lepidoptera	
	250g Roses					+	Lepidoptera	*Paralipsa gularis*
	250g Roses		QLD			+	Lepidoptera	*Plodia interpunctella*
	250g Roses					+	Lepidoptera	
	250g Roses					+	Lepidoptera	
	250g Roses					+	Lepidoptera	
	250g Roses					+	Lepidoptera	
	250g Roses					+	Lepidoptera	
	250g Roses					+	Lepidoptera	
	250g Roses					+	Lepidoptera	
	300g Milk Tray	Lavington	NSW	Lavington	NSW	+	Lepidoptera	*Plodia interpunctella*
	300g Roses	Duncraig	WA			+	Lepidoptera	*Plodia interpunctella*
	500g Milk Tray	Bridgeman Downs	QLD			+	Lepidoptera	
	500g Milk Tray	Colovale	NSW	Campbelltown	NSW	+	Lepidoptera	*Ephestia cautella*
	500g Milk Tray	Dubbo	NSW			+	Lepidoptera	
	500g Milk Tray	Heathcote	NSW			+	Lepidoptera	
	500g Milk Tray	Illawong	NSW			+	Lepidoptera	*Plodia interpunctella*
	500g Milk Tray	Mackay	QLD	Mackay	QLD	+	Lepidoptera	*Ephestia cautella*
	500g Milk Tray	Morley	WA			+	Lepidoptera	
	500g Milk Tray	Oak Flats	NSW	Sylvania	QLD	+	Lepidoptera	*Ephestia cautella*
	500g Milk Tray	Roseville	NSW			+	Lepidoptera	*Plodia interpunctella*
	500g Milk Tray	Toorak	VIC			+	Lepidoptera	*Plodia interpunctella*
	500g Milk Tray					+	Lepidoptera	
	500g Milk Tray					+	Lepidoptera	
	500g Roses	Gladstone	QLD	Gladstone	QLD	+	Lepidoptera	

APPENDIX V

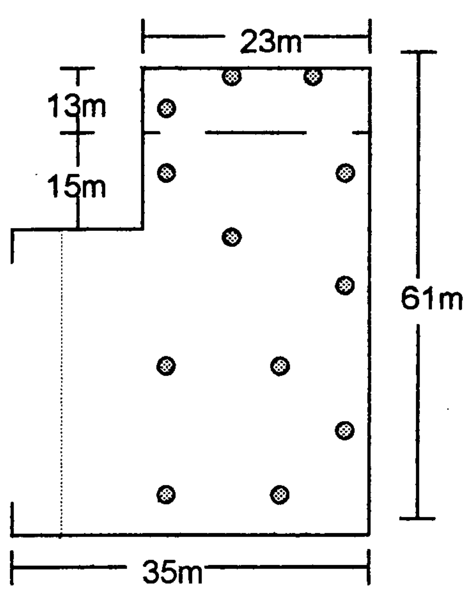
Product group	Product	Customer district	state	Retail outlet district	state	Nut ingredient	Pest type	Identification
	500g Roses	Mackay	QLD			+	Lepidoptera	*Plodia interpunctella*
	500g Roses	Manning	WA			+	Lepidoptera	*Plodia interpunctella*
	500g Roses	Turramurra	WA			+	Lepidoptera	
	500g Roses					+	Lepidoptera	*Ephestia cautella*
	500g Roses		VIC			+	Lepidoptera	*Ephestia elutella*
Bars	30g Flake	Bradbury	NSW			-	Lepidoptera	
	55g Turkish Delight	Gingin	WA	Leeman	WA	-	Lepidoptera	
	55g Turkish Delight	Saratoga	NSW			-	Lepidoptera	
Children's	5*15g Dairy Milk					-	Lepidoptera	*Plodia interpunctella*
Moulded	100g Hazel Nut Milk P-P	Christmas Island	WA			+	Lepidoptera	
	150g Black Forest	East Victoria Pk	WA			-	Lepidoptera	
	15g Caramilk	Ballambi	NSW			-	Lepidoptera	
	250g Brazil Nut Milk	Lake Cargelligo	NSW			+	Lepidoptera	*Plodia interpunctella*
	250g Caramello	Bar Beach	NSW	Charleston	NSW	-	Lepidoptera	*Ephestia cautella*
	250g Caramello	Nth Carlton	VIC	Nth Carlton	VIC	-	Lepidoptera	*Plodia interpunctella*
	250g Cashew Nut Milk	Bundall	QLD			+	Lepidoptera	*Ephestia cautella*
	250g Cashew Nut Milk	Redbank Plains	QLD			+	Lepidoptera	*Ephestia elutella*
	250g Chocolate Crackle	Cardwell	QLD	Tully	QLD	-	Lepidoptera	
	250g Chocolate Crackle	Karratha	WA	Karatha	WA	-	Lepidoptera	
	250g Dairy Milk	Nth Richmond	NSW			-	Lepidoptera	
	250g Fruit & Nut Milk	Lugarno	NSW			+	Lepidoptera	
	250g Fruit & Nut Milk	Mosman	NSW			+	Lepidoptera	*Plodia interpunctella*
	250g Fruit & Nut Milk	St Lucia	QLD			+	Lepidoptera	
	250g Hazel Nut Milk	Bray Park	QLD			+	Lepidoptera	
	250g Hazel Nut Milk	Currumbin Beach	QLD			+	Lepidoptera	
	250g Hazel Nut Milk	Gladstone	QLD			+	Lepidoptera	
	250g Hazel Nut Milk	Hectorville	SA			+	Lepidoptera	
	250g Hazel Nut Milk	Lake Cargelligo	NSW			+	Lepidoptera	
	250g Hazel Nut Milk	Lurnea	NSW			+	Lepidoptera	
	250g Hazel Nut Milk	Warrandyte	VIC			+	Lepidoptera	*Ephestia elutella*
	250g Nut Mix	High Wycombe	NSW			+	Lepidoptera	
	250g Roast Almond	Kingsley	WA			+	Lepidoptera	
	250g Roast Almond	Nedlands	WA			+	Lepidoptera	*Plodia interpunctella*
	250g Roast Almond	O'Connor	ACT			+	Lepidoptera	
	250g Rocky Road	Wickham	WA			+	Lepidoptera	
	250g Swiss Chalet	Marangaroo	WA			-	Lepidoptera	
	275g Fruit & Nut Milk	Lake Cargelligo	NSW			+	Lepidoptera	*Plodia interpunctella*
	55g Caramello Roll	Nth Sydney	NSW			-	Lepidoptera	
	55g Caramello Roll	Old Beach	TAS	Claremont	TAS	-	Lepidoptera	
	55g Dairy Milk	Tamworth	NSW			-	Lepidoptera	
	55g Dairy Milk Roll	McKinnon	VIC	McKinnon	VIC	-	Lepidoptera	
	55g Fruit & Nut Milk	Dianella	WA	Dianella	WA	+	Lepidoptera	*Plodia interpunctella*
	55g Hazel Nut Milk	Mt Lawley	WA			+	Lepidoptera	*Plodia interpunctella*
	55g Peppermint	Ridgeley	TAS	Ridgeley	TAS	-	Lepidoptera	
	55g Peppermint Roll	Nimbin	NSW	Holland Park	QLD	-	Lepidoptera	
	55g Roast Almond	Acland	QLD			+	Lepidoptera	*Ephestia cautella*

APPENDIX VI

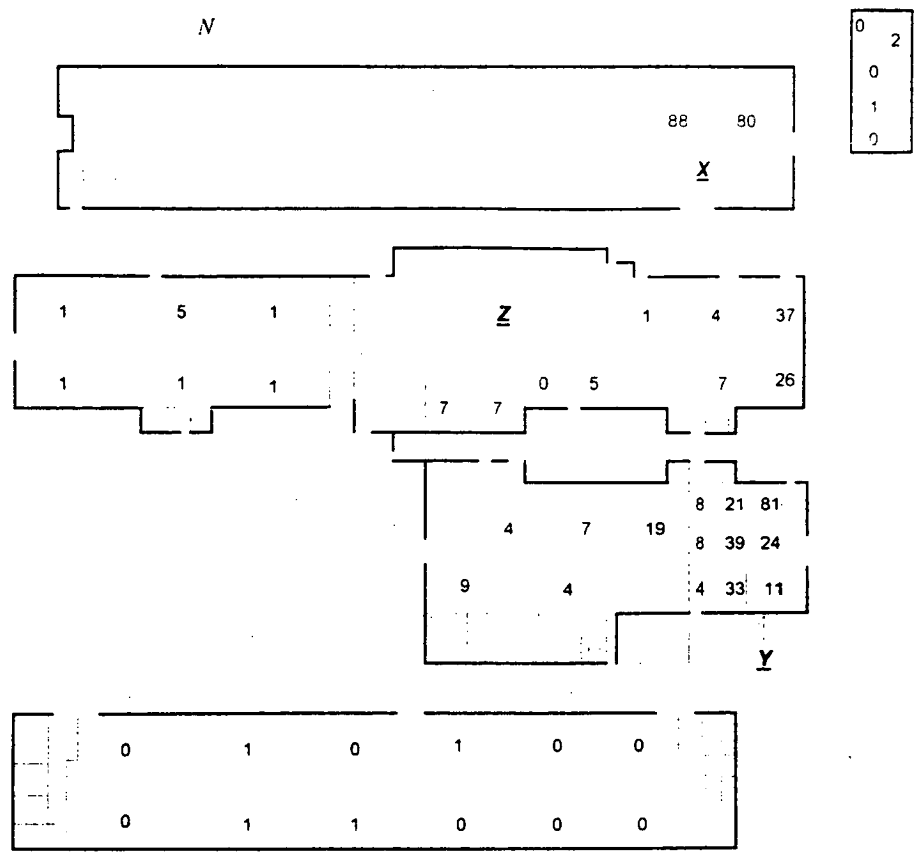
Welshpool distribution centre (Western Australia)



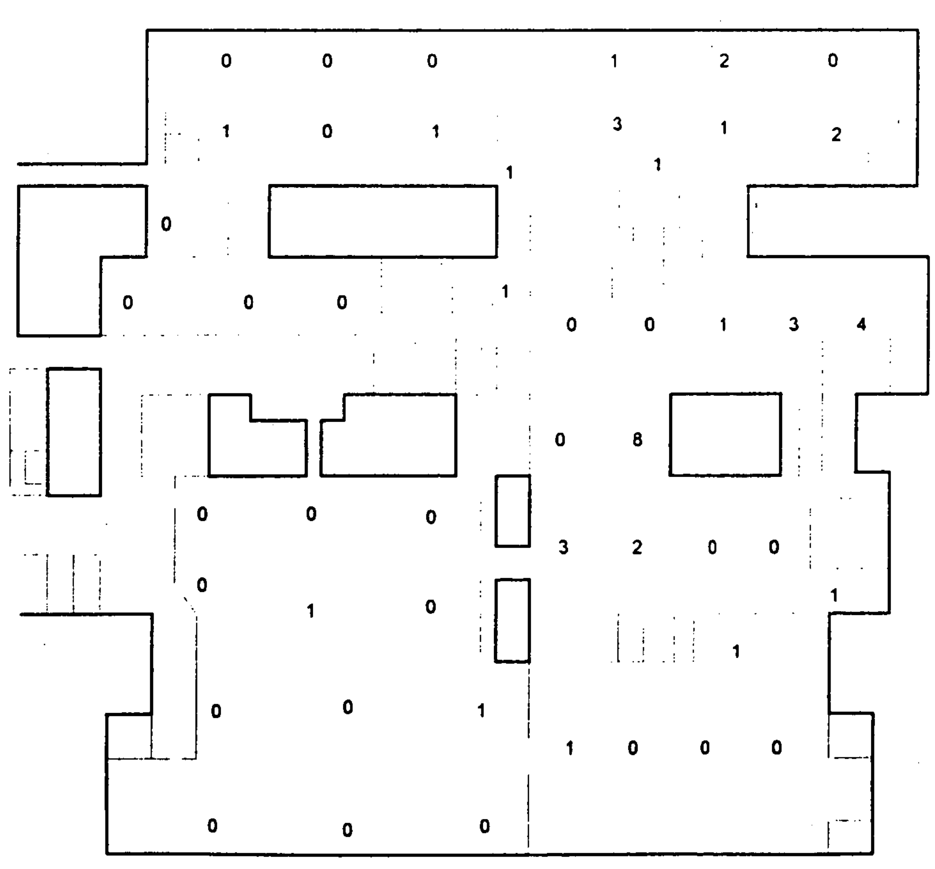
Hindmarsh distribution centre (South Australia)



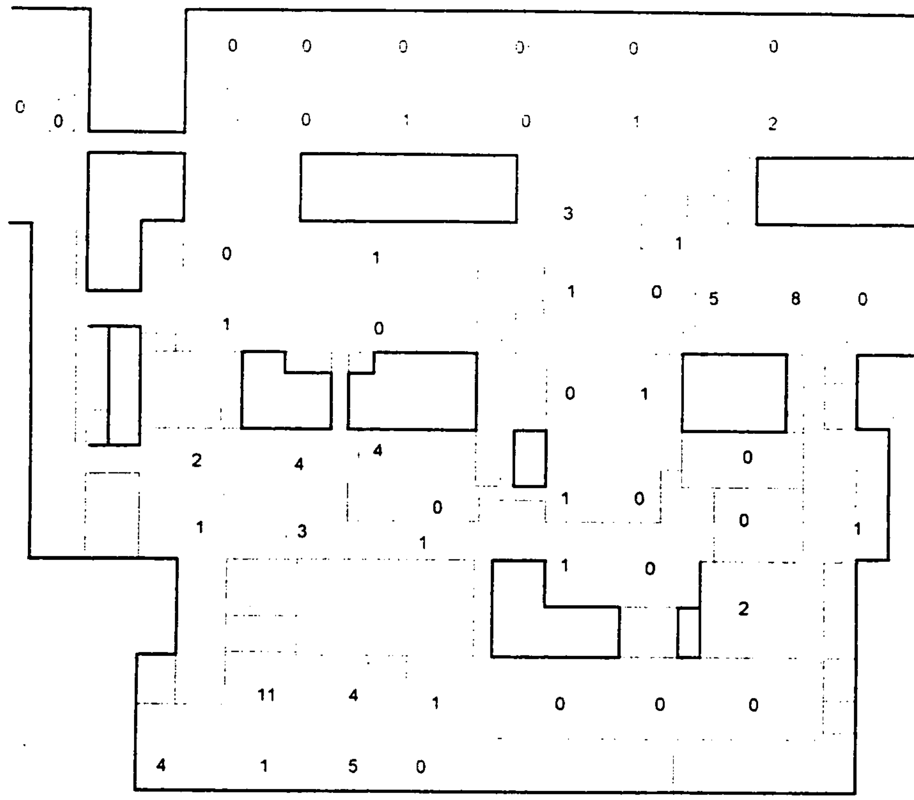
APPENDIX VII (Ground Floor)



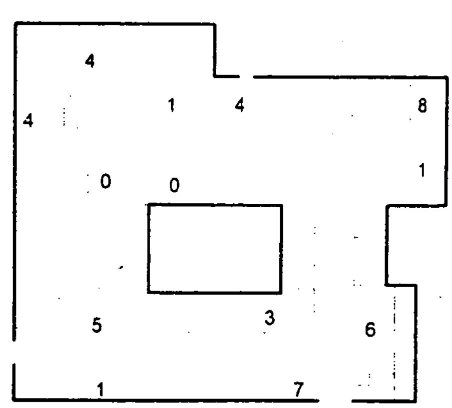
APPENDIX VII (First Floor)



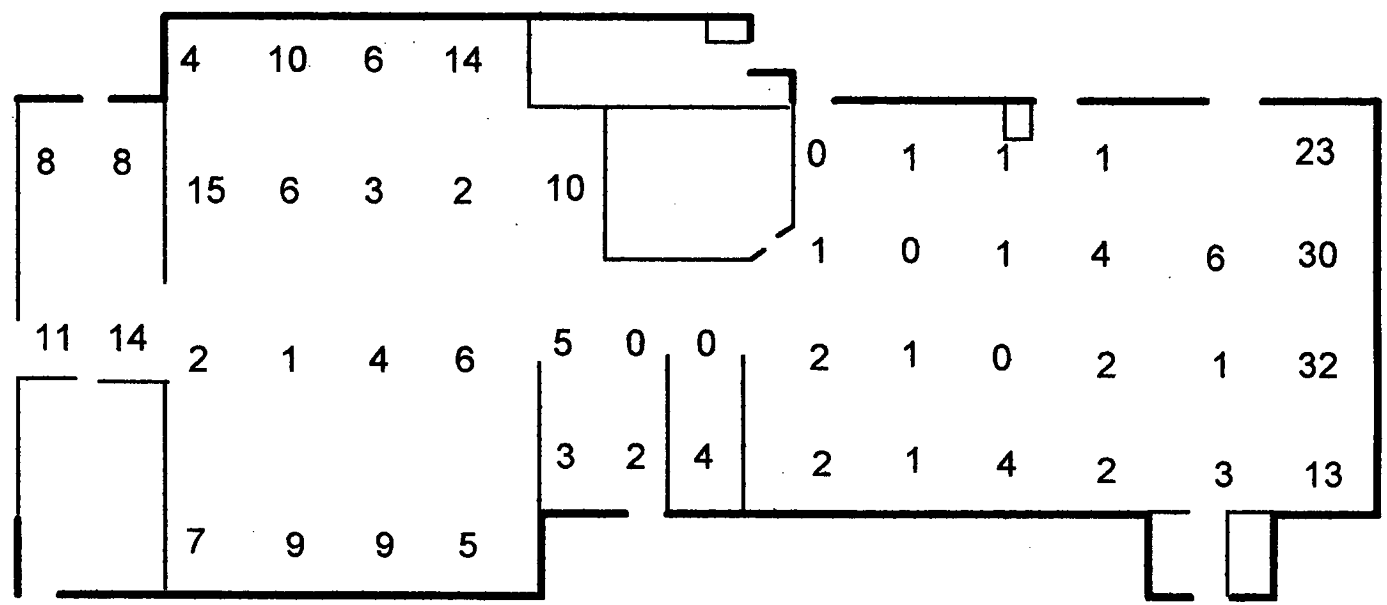
APPENDIX VII (Second Floor)



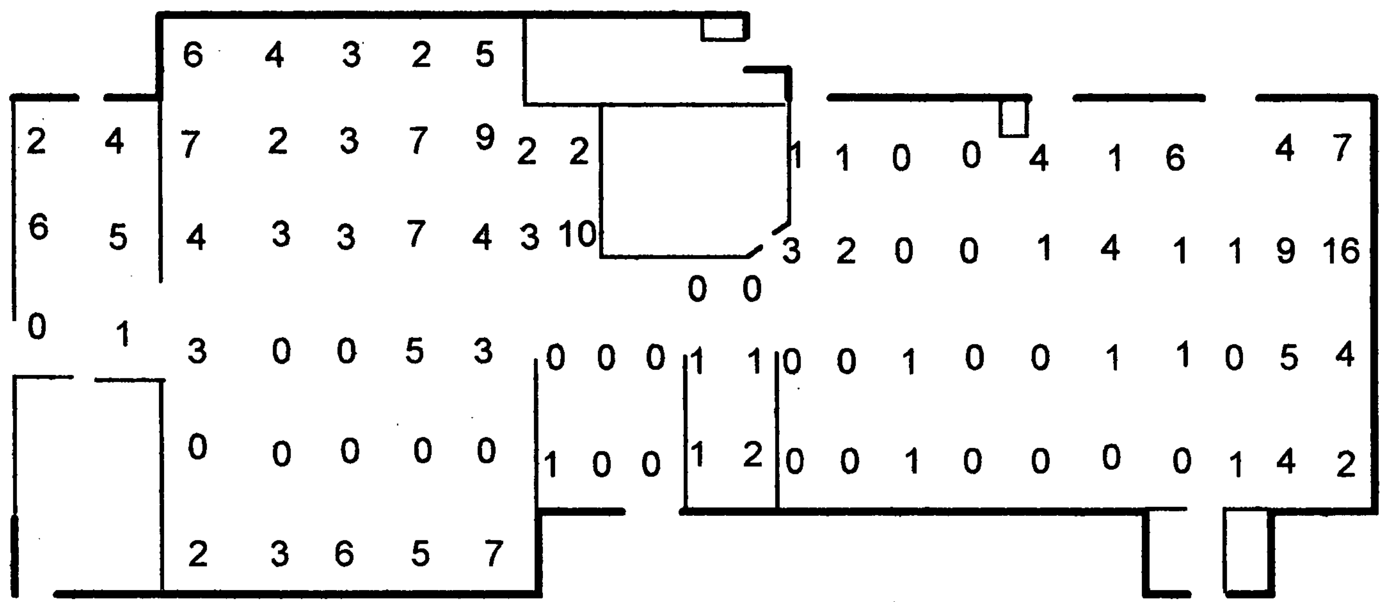
APPENDIX VII (Third Floor)



APPENDIX VIII (Room Z, August 1994-January 1995)



APPENDIX IX (Room Z, January 1995-June 1995)



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Bowditch T. G., Madden J. L. and Brassington B. F. (1994) Field evaluation of a cylinder trap design for monitoring Ephestia cautella.
In Proc. 6th Int Work. Conf. Stored-Prod Prot.
(Edited by Highley E., Wright E. J., Banks H. J. and Champ B. R.), pp. 1233-1234. Canberra, Australia, 1994.